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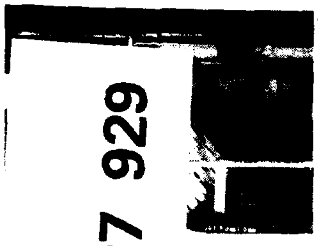





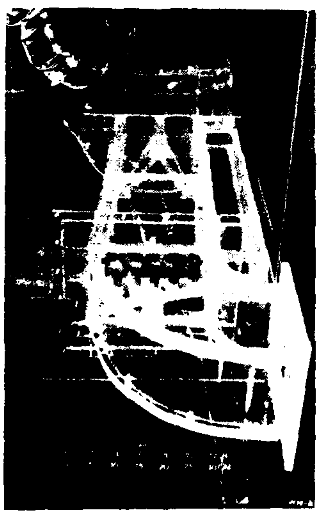

HYDRAULICS LABORATORY

(2)

TECHNICAL REPORT HL-90-9

# RED RIVER WATERWAY
# REVISED OUTLETS FOR RED RIVER LOCKS

## Hydraulic Model Investigation

by

Richard L. Stockstill

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199



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19. ABSTRACT (Continue on reverse if necessary and identify by block number)


Sediment accumulation near the lower miter gates at Lock 1 on the Red River Waterway, Louisiana, caused difficulties in the operation of the lock. Sediment located this close to the structure could not be removed by typical means of dredging. A study using a 1:25-scale model was conducted to determine if modification of the lock's emptying system would eliminate or reduce the amount of sediment depositing in the vicinity of the lower miter gates. The resulting modification that proved most feasible could be included in the emptying system design for Locks 4 and 5 on the Red River Waterway.

To determine qualitatively the effectiveness of various outlet designs, crushed coal was placed in the vicinity of the lower miter gates and the amount of coal displaced during emptying operations was used as a comparison.

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19. ABSTRACT (Continued).

An outlet area design including baffles in front of the discharge manifold wall ports and a manifold designed specifically to flush sediment from the lower miter gates resulted in the crushed coal being removed during a lock emptying operation for the condition of maximum lift and for the condition of minimum lift when steady flow through the emptying system was maintained for 30 min (prototype). Designs incorporating more standardized sidewall manifolds combined with recessed pits in front of the manifold ports were developed that would also perform satisfactorily. Keywords: Locks waterways; Sediments deposition flushing; → (to p1)

# PREFACE

The model investigation reported herein was authorized by Headquarters, US Army Corps of Engineers, on 10 July 1987 at the request of the US Army Engineer District, Vicksburg (LMK). The studies were conducted by personnel of the Hydraulics Laboratory (HL), US Army Engineer Waterways Experiment Station (WES), during the period October 1987 to September 1988.

All studies were conducted under the direction of Messrs. F. A. Herrmann, Jr., Chief, HL; R. A. Sager, Assistant Chief, HL; and G. A. Pickering, Chief, Hydraulic Structures Division (HSD), HL. The model components were constructed and assembled by Messrs. E. B. Williams, R. L. Blackwell, and E. A. Case, Engineering and Construction Services Division, WES. Hydraulic design and consultation were provided by Dr. F. M. Neilson, Hydraulic Engineering Information Analysis Center, HSD. The tests were conducted by Messrs. R. L. Stockstill, M. W. Ott, and V. E. Stewart, Locks and Conduits Branch, HSD, under the supervision of Mr. J. F. George, Chief, Locks and Conduits Branch. This report was prepared by Mr. Stockstill and edited by Mrs. M. C. Gay, Information Technology Laboratory, WES.

Messrs. Larry Cook, Malcolm Dove, and Joe McCormick, US Army Engineer Division, Lower Mississippi Valley; and Phil Combs, Fred Pinkard, Rick Robertson, Terry Smith, and Jamie Triplett, LMK, visited WES during the course of the model study to observe model operation and correlate results with design works.

Commander and Director of WES during preparation of this report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

CONTENTS

## CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

| Multiply | By | To Obtain |
|---|---|---|
| feet | 0.3048 | metres |
| miles (US statute) | 1.609347 | kilometres |
| square feet | 0.09290304 | square metres |

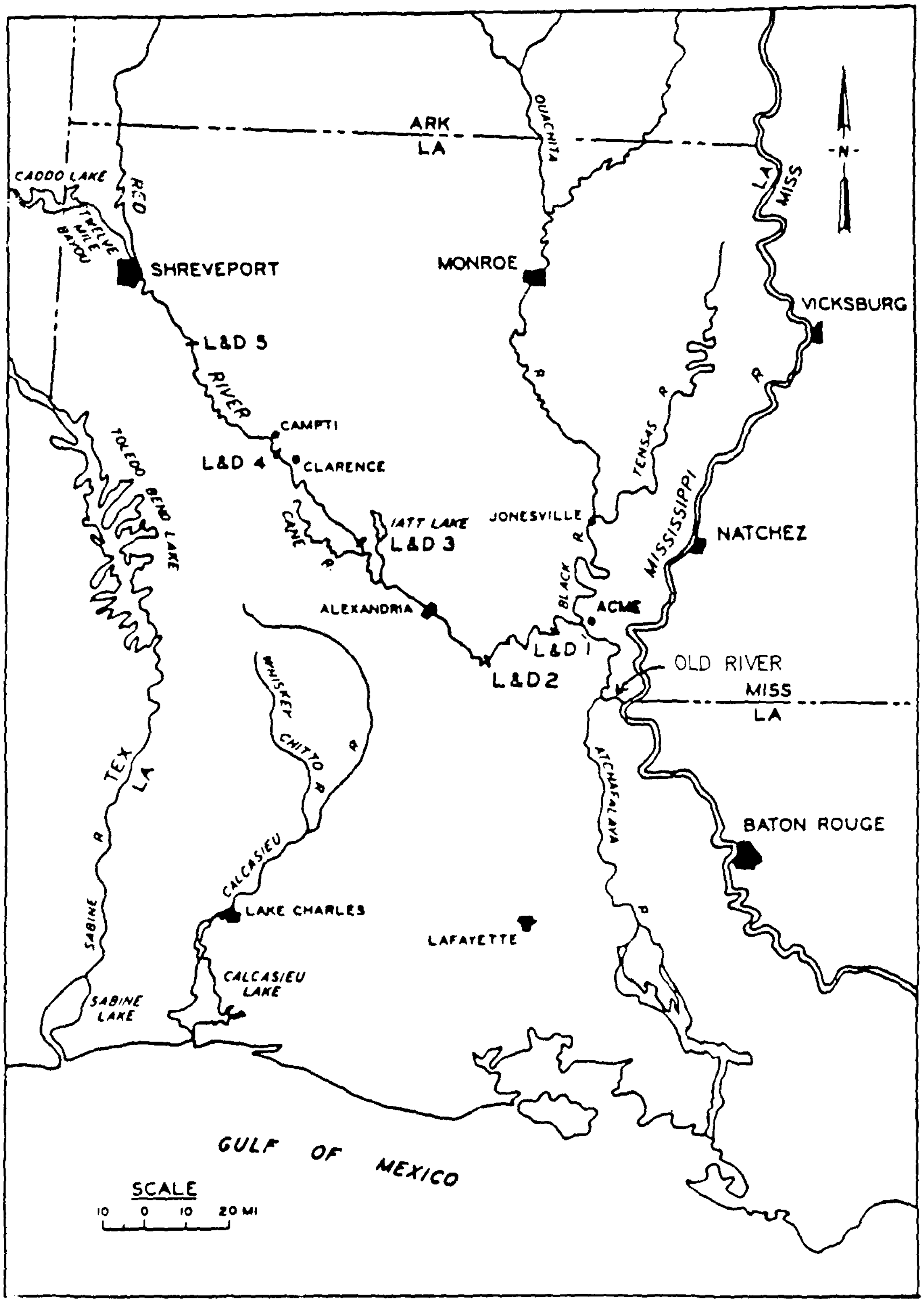


Figure 1. Location map

# RED RIVER WATERWAY, REVISED OUTLETS FOR RED RIVER LOCKS

## Hydraulic Model Investigation

## PART I: INTRODUCTION

### The Prototype

1. Construction of the Red River Waterway, Louisiana, was authorized 13 August 1968. The project will provide, in part, a navigation route from the Mississippi River at its junction with Old River via Old and Red Rivers to Shreveport, LA (Figure 1). The improvement includes development of a channel approximately 236 miles* long (realigned), 9 ft deep, and 200 ft wide. The development of the channel will consist of construction of a system of five locks and dams to furnish the required cumulative maximum lift of 141 ft. The sites of these dams and navigation structures are shown in Figure 2. Lock and Dam 1 was in operation, Lock and Dam 2 was essentially complete, the design of Lock and Dam 3 was complete, and Locks 4 and 5 were still in the planning stage when this investigation was initiated.

Lock design

2. The locks to be used in the Red River structures are to be 84 ft wide with a usable length of 685 ft. Pintle-to-pintle spacing of the miter gates will be 785 ft. The filling and emptying systems for the locks will use a 12- by 12-ft longitudinal culvert in each lock wall and will be similar to the systems that were developed in previous hydraulic model investigations.**,† Design changes were limited to the discharge manifold and outlet area.

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* A table of factors for converting non-SI units of measurements to SI (metric) units is found on page 3.

** J. H. Ables and M. B. Boyd. 1966 (Nov). "Filling and Emptying Systems, Low-Lift Locks, Arkansas River Project; Hydraulic Model Investigation," Technical Report 2-743, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

† N. R. Oswalt, J. H. Ables, M. B. Boyd, and T. E. Murphy. 1965 (Jun). "Filling and Emptying System, Jonesville Lock, Ouachita-Black Rivers, Louisiana; Hydraulic Model Investigation," Technical Report 2-678, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

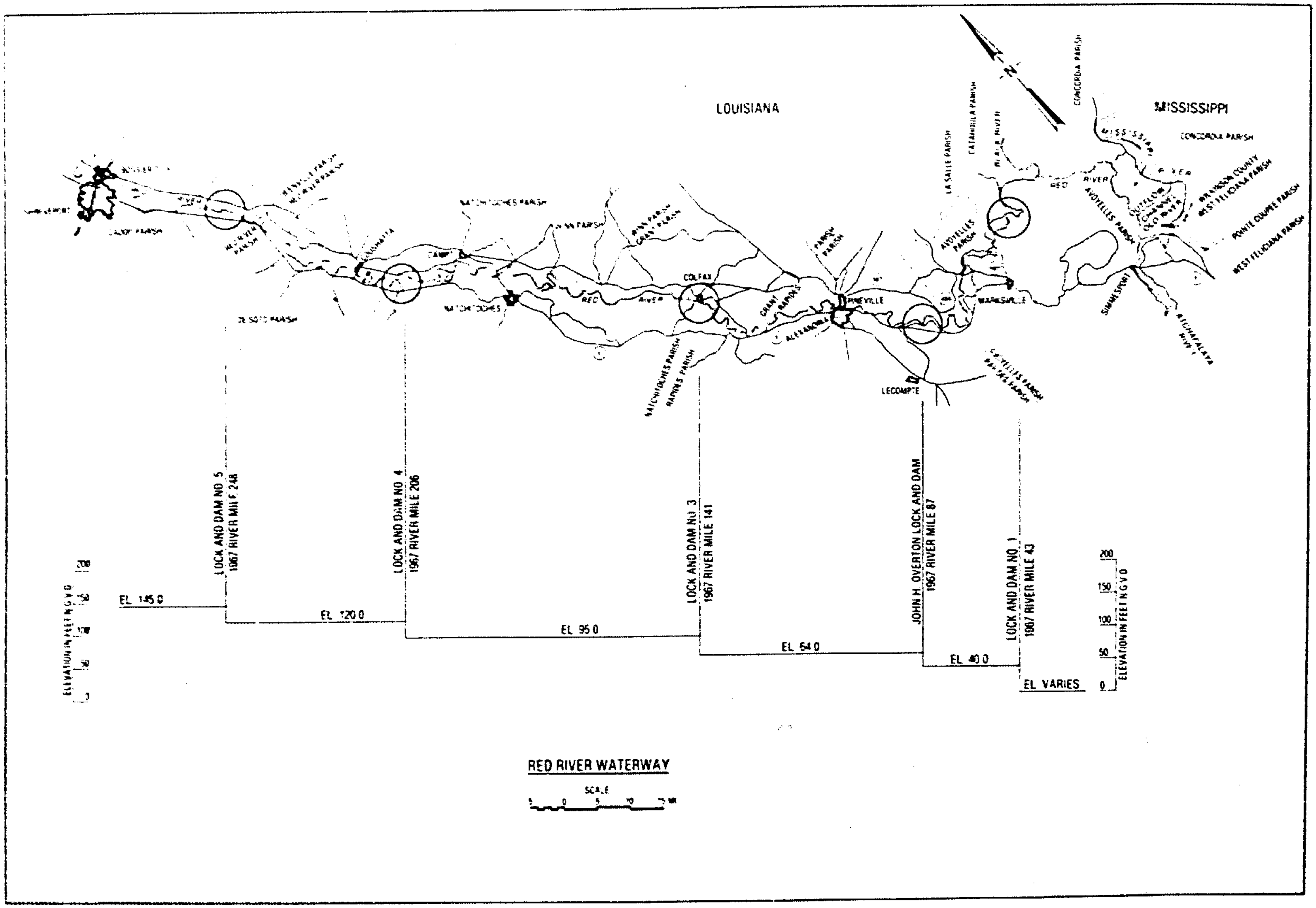


Figure 2. Waterway plan and profile

Problems associated with sediment

3. Sediment accumulation near the lower miter gates of Lock 1 caused difficulties. A substantial amount of sediment accumulated in a mound resting against the downstream side of the lower miter gates. When the miter gates were opened, the material shifted upstream, encroaching on the gate pathway. When closure of the miter gates was attempted, the resistance created by the pile of material resulted in a structural failure of a gate pintle. Sediment located this close to the structure could not be removed by typical means of dredging.

Conventional discharge manifold and outlet area

4. The discharge manifold used on Red River Lock 1 was a conventional sidewall manifold that was based on the design used for the Arkansas River locks* and on modifications following the same pattern as the Jonesville Lock discharge manifold.** These conventional manifolds were oversized with regard to capacity in favor of energy dissipation within the manifold structure. The capability of flushing sediment in the vicinity of the miter gates was not a consideration in the conventional discharge and outlet area design.

## Purpose of the Model Study

5. Because of the problem associated with the accumulation of sediment, a model study was needed to determine if modification of the lock's emptying system would eliminate or reduce the amount of sediment in the vicinity of the lower miter gates. The resulting modifications that proved most feasible could be included in the emptying system design for Locks 4 and 5.

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* Ables and Boyd, op. cit.
** Oswalt et al., op. cit.

## PART II: THE MODEL

### Description

6. The model, constructed to a scale of 1:25, reproduced the lock chamber, the lock emptying system, culvert tainter valves, and approximately 500 ft of the downstream approach (Figure 3). The elevations used on the model study were the elevations corresponding to the proposed Lock and Dam 4. The lock chamber was constructed of plastic-coated plywood, and the valve wells, culverts, and discharge manifolds were constructed of transparent plastic and sheet metal. The culvert valves were constructed of sheet metal.

### Model Appurtenances

7. Water was supplied to the model through a circulating system. Water-surface elevations were measured with point gages, and dye was used to study current directions. Different designs, test results, and flow conditions were recorded photographically.

8. The movement of the culvert valves was controlled by servo-driven linear actuators that were regulated by the output of a microcomputer. The microcomputer was programmed to reproduce the desired valve schedules.

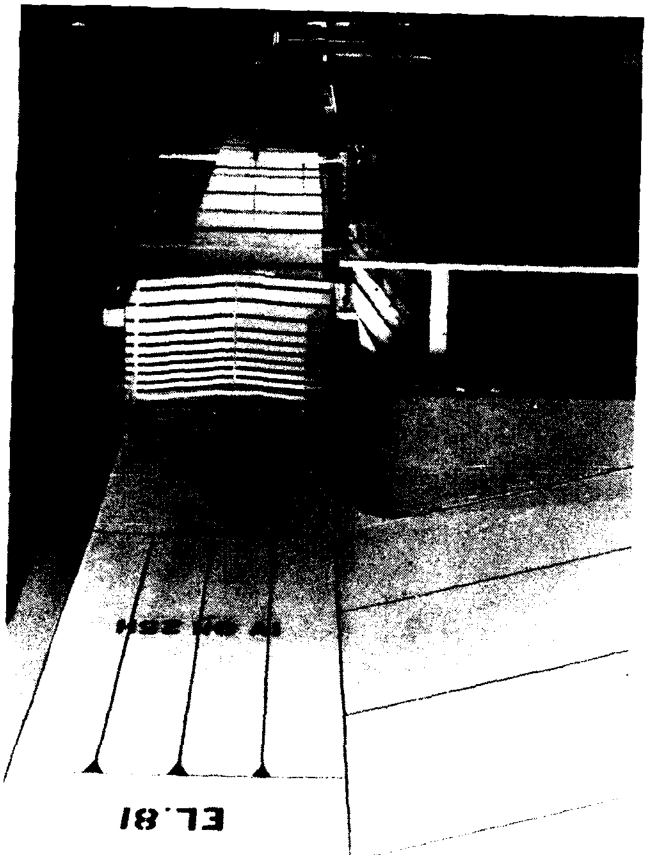
### Scale Relations

9. The accepted equations of hydraulic similitude, based on Froudian relations, were used to express mathematical relations between the dimensions and hydraulic quantities of the model and prototype. General relations for transference of model data to prototype equivalents are shown in the following tabulation:

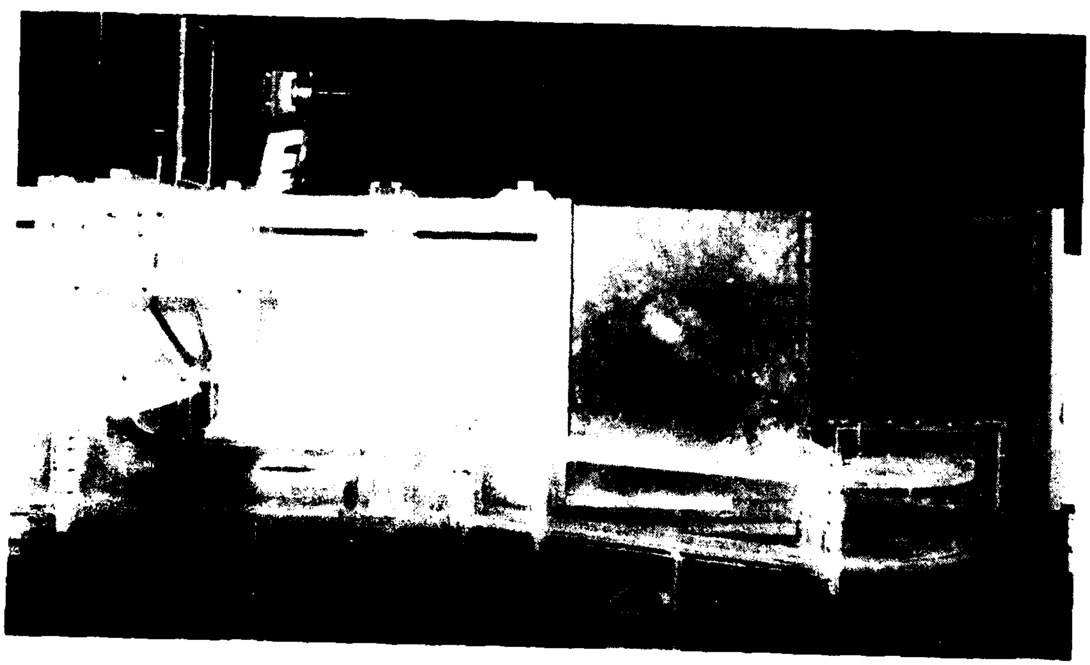
| Characteristic | Dimension* | Scale Relations Model:Prototype |
|---|---|---|
| Length | $L_r = L$ | 1:25 |
| Area | $A_r = L_r^2$ | 1:625 |
| Velocity | $V_r = L_r^{1/2}$ | 1:5 |
| Time | $T_r = L_r^{1/2}$ | 1:5 |
| Discharge | $Q_r = L_r^{5/2}$ | 1:3,125 |

* Dimensions are in terms of length.

Because of the nature of the phenomena involved, certain model data can be accepted quantitatively, while other data are reliable only in a qualitative sense. Measurements in the model of discharges, water-surface elevations, and velocities can be transferred quantitatively from model to prototype using these scale relations.



a. General view



b. Right emptying valve and culvert

Figure 3. The 1:25-scale model, type 1 (original) design

## PART III: TESTS AND RESULTS

### Type 1 Design Outlet Area

10. The type 1 (original) design outlet area included the use of the type 1 design discharge manifold, which was designed specifically to flush sediment from the lower miter gates while maintaining lock emptying efficiency. This design was not the standard discharge manifold proposed for the Red River locks, but was a unique design developed at the US Army Engineer Waterways Experiment Station (WES). The type 1 design discharge manifold, shown in Figure 4 and Plates 1 and 2, consisted of thirty-two 2-ft-wide by 3-ft-high ports at el 70,* which issued jets in the upstream and downstream directions, and six . .5-ft-wide by 6-ft-high ports located in each lock wall at el 75, resulting in a total port-to-culvert-area ratio of 1.04 (port area of 150 sq ft per 12- by 12-ft culvert).

11. Velocities at each of the discharge manii ( ports (Plate 3) were measured during steady-flow conditions. The sum of the flow out of the ports located on the left and right lock walls was 40 percent of the total flow. The ports in the floor manifold discharging in the upstream direction (toward the miter gates) discharged 28 percent of the total flow. The ports in the floor manifold discharging in the downstream direction discharged 32 percent of the total flow.

12. To determine qualitatively the effectiveness of various designs, crushed coal was placed in the vicinity of the lower miter gates and the amount of coal displaced during emptying operations was used for comparison. Crushed coal was used because it was light and noncohesive and could be easily observed.

13. Tests conducted with the type 1 design outlet area (Figure 5, Plate 4) showed that a significant portion of the coal was removed from the vicinity of the miter gates during an emptying operation for maximum lift conditions.** However, the coal was not adequately flushed with minimum

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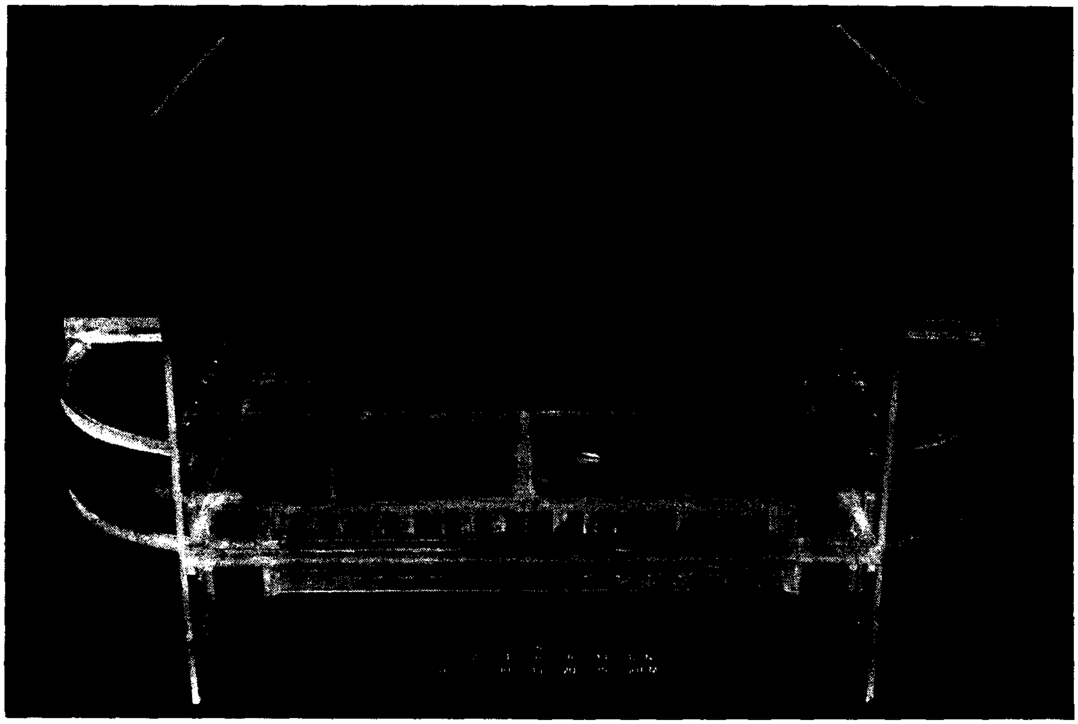
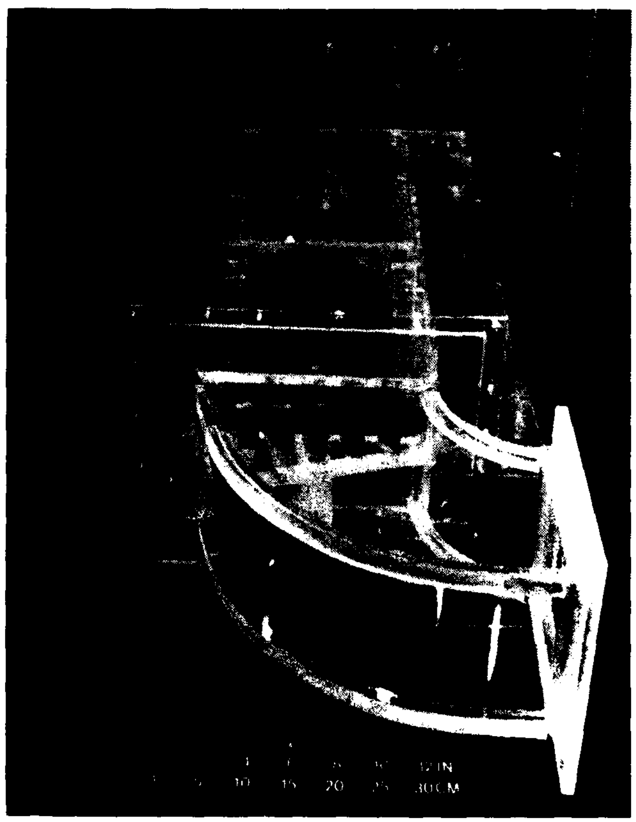
* All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

** Maximum lift condition was for an upper pool el of 120.0, a lower pool el of 95.0, and an initial head of 25 ft, whereas minimum lift condition was for an upper pool el of 121.7, a lower pool el of 118.2, and an initial head of 3.5 ft.



a. View from lock center line, looking upstream



b. View from left of lock, looking toward right

Figure 4. Type 1 (original) design discharge manifold

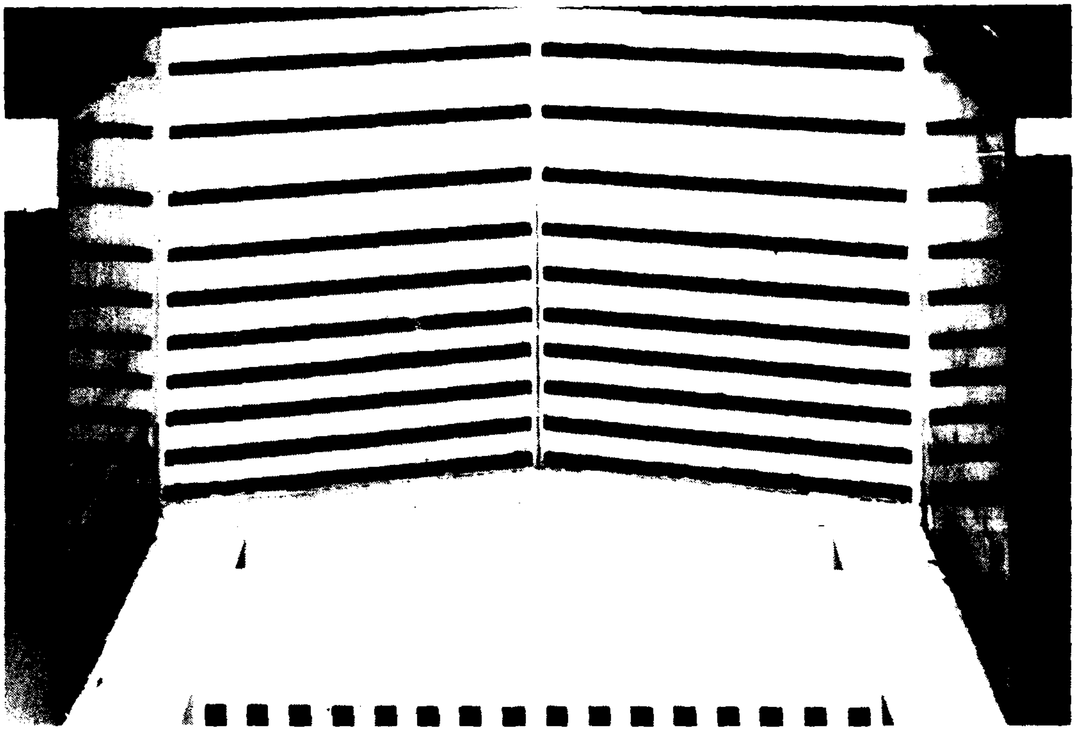


Figure 5. Type 1 (original) design outlet area

lift conditions nor when steady flow through the emptying system was maintained for 1 hr (prototype) with the emptying valves fully opened. These test results are shown in Photo 1. Virtually all movement of coal ceased after 1 hr (prototype) with steady-flow conditions. Therefore, 1 hr was selected as the maximum time duration for steady-flow tests. Photos 2 and 3 show flow conditions associated with the type 1 design outlet area during 4-min normal and single-valve emptying operations for maximum and minimum lift conditions, respectively.

## Type 2 Design Outlet Area

14. Modifications were made to the outlet area associated with the type 1 design discharge manifold. A slope was placed on the downstream face of the lower miter sill in an effort to eliminate the areas where the coal tended to collect during emptying operations. This was designated the type 2 design outlet area and is shown in Figure 6 and Plate 5. With maximum lift conditions all of the coal was removed from the vicinity of the miter gates during one emptying operation. Some of the coal was present near the pintles

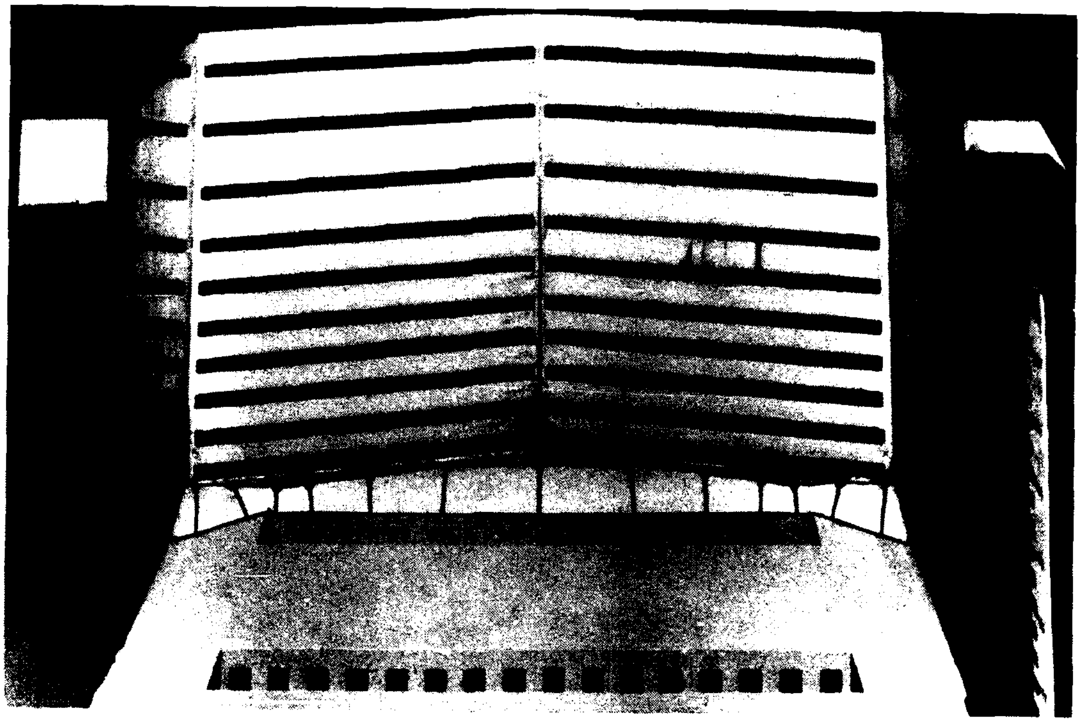


Figure 6. Type 2 design outlet area

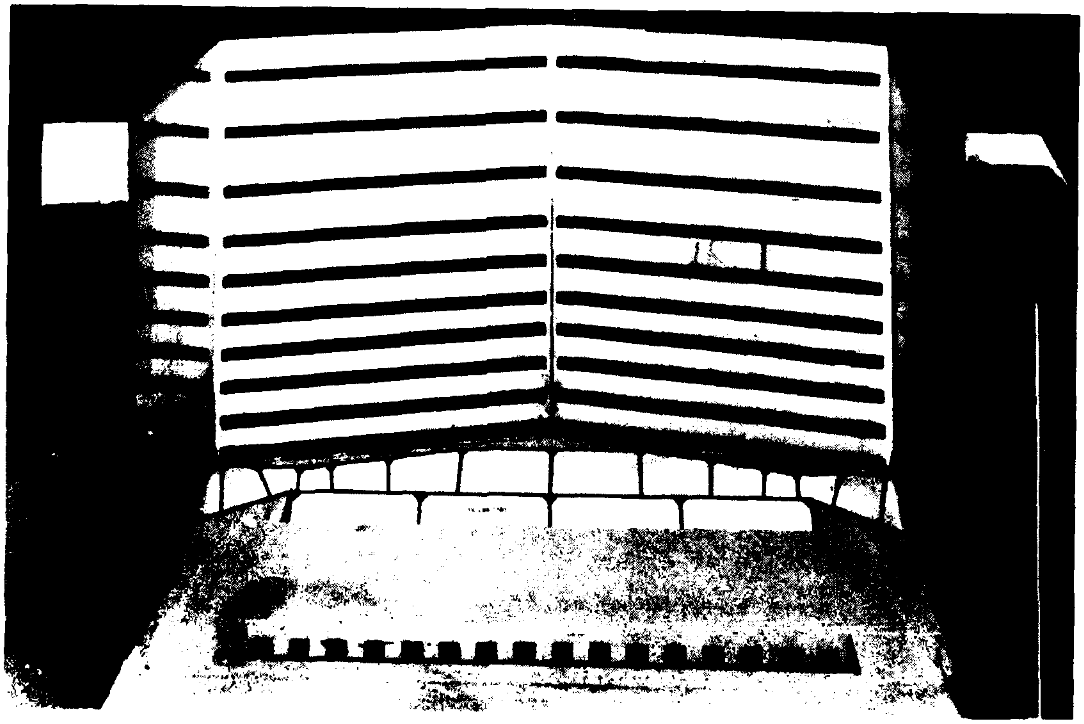


Figure 7. Type 3 design outlet area

after one emptying operation with minimum lift conditions. However, all coal was removed using the type 2 design outlet area for minimum lift conditions when steady flow through the emptying system was maintained for 1 hr (prototype). The type 2 design outlet area with coal placed in the vicinity of the downstream miter gates before and after each emptying operation for maximum and minimum lift conditions is shown in Photo 4.

## Type 3 Design Outlet Area

15. In order to improve the lock's flushing capability for minimum lift conditions, a 1V on 1.6H slope was installed in the pits of the type 1 design discharge manifold (type 3 design outlet area, Figure 7, Plate 6). The coal was placed in suspension with the type 3 design outlet area, but did not move downstream and at the end of the emptying cycle was deposited in the vicinity of the gates. Flow jets from the upstream ports located in the pit also struck the miter gates, which could result in adverse loads being placed on the miter gates.

## Type 4 Design Outlet Area

16. To assist in dissipating energy in the jets issuing from the wall ports of the type 1 design discharge manifold, baffles were added to the type 2 design outlet area. This was designated the type 4 design outlet area (Figure 8, Plate 7). The 1.5-ft-wide by 2.0-ft-high baffles were located a distance of one port height (6.0 ft) in front of the manifold ports.

17. A dry-bed photograph of the type 4 design outlet area with coal placed near the miter gates is shown in Photo 5a. Photo 5b, taken after one emptying operation at maximum lift condition, illustrates that all the coal was removed. One emptying operation at minimum lift did not remove all the coal (Photo 5c); however, when the emptying valves were fully open for a period of 30 min (prototype) at the condition of minimum lift, the miter gate area was adequately flushed. Test results indicated that the addition of baffles improved the flushing capability of the outlet and reduced bulking during emptying. The coal remaining after steady flow at the condition of minimum lift for periods of 30 and 60 min is shown in Photos 5d and 5e, respectively. Flow conditions during emptying operations with the type 4 design outlet area are presented in Photos 6 and 7.

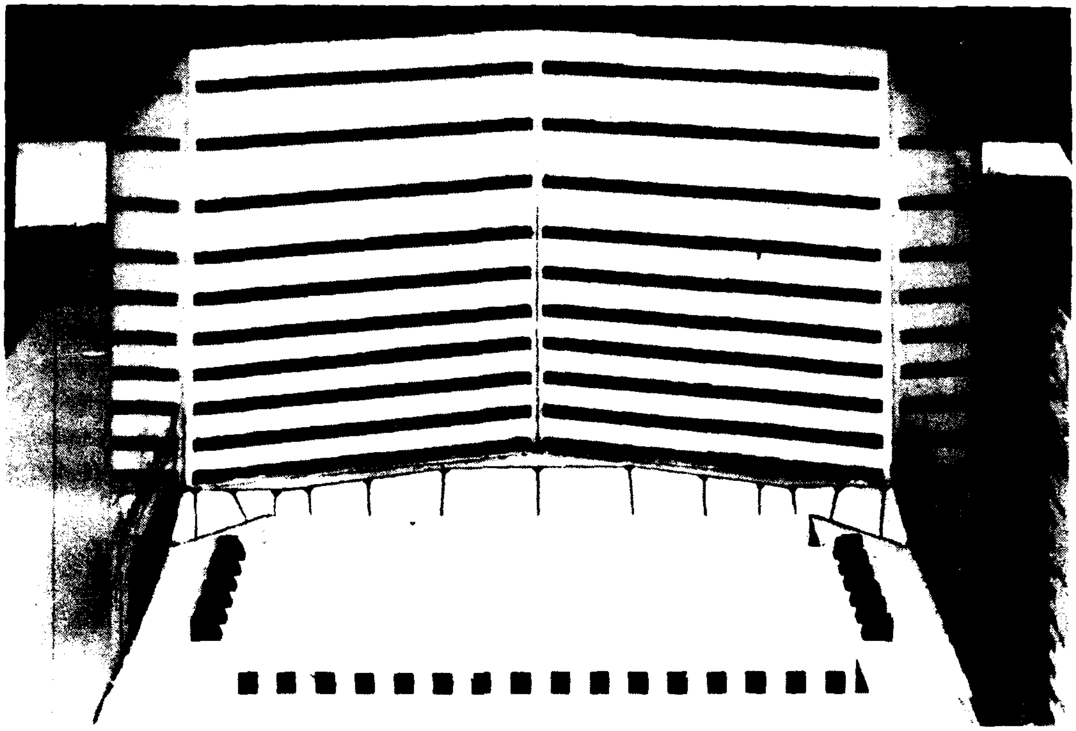


Figure 8. Type 4 design outlet area

18. From observations and test results, it was determined that not enough turbulence was present during one emptying operation at minimum lift conditions using any of the design types to flush out the coal from the vicinity of the miter gates. From the designs tested that incorporated the unique manifold, the type 4 outlet area provided the most efficient design to flush out the coal just downstream of the miter gates. From this point in the testing program, efforts were redirected toward evaluating an emptying system incorporating a more conventional manifold design.

## Type 5 Design Outlet Area

19. A conventional sidewall discharge manifold similar to the design used on Red River Lock 1 (type 2 design discharge manifold, Plate 8) was installed in the model to determine if this type of manifold and outlet area could be modified to adequately flush sediment during emptying operations. The type 2 design discharge manifold consisted of eight 4.5-ft-wide by 7-ft-high ports located in each lock wall, resulting in a total port-to-

culvert-area ratio of 1.75 (port area of 252 sq ft per 12- by 12-ft culvert). The invert of the pit in which the manifold ports discharged was sloped downward away from the port faces at a slope of 1V on 5H. The upstream edge of the upstream port of the manifold was located at sta 8+35. This was designated the type 5 design outlet area (Figure 9, Plate 9).

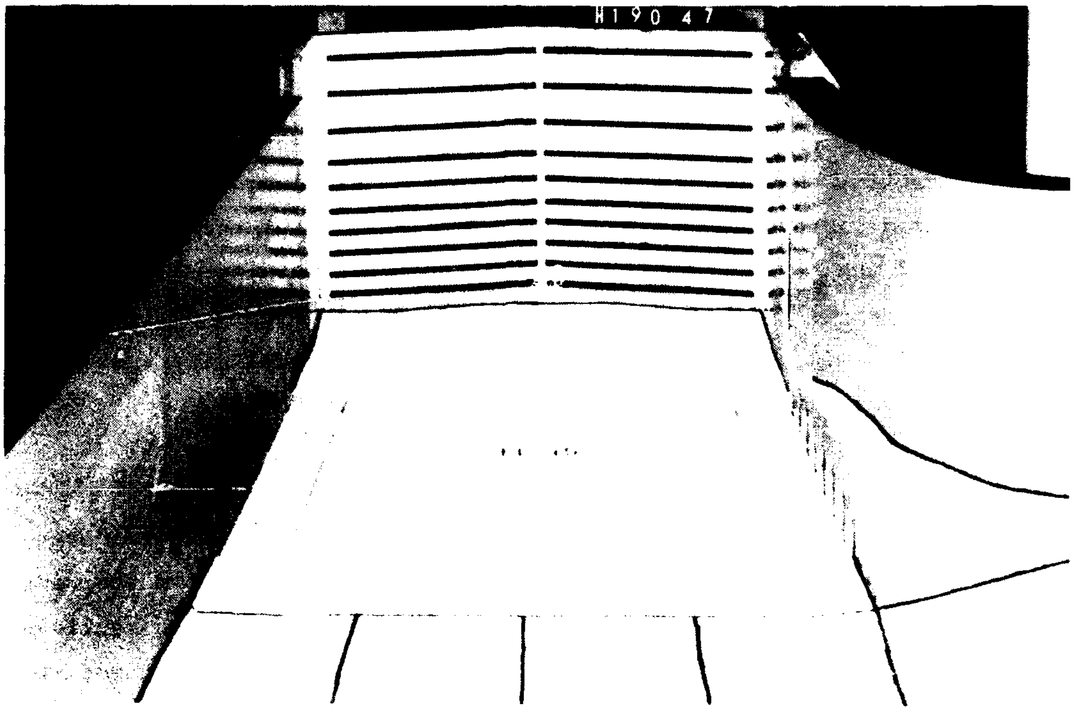


Figure 9. Type 5 design outlet area

20. Steady-flow tests were conducted to determine the flow distribution in the eight-port manifold. Pertinent velocity data and a plot showing the flow distribution are presented in Plate 10. Flow out of the manifold ports was not balanced because the large port-to-culvert-area ratio resulted in flow control at the culverts rather than at the outlets.

21. Tests conducted with the type 5 design outlet area showed that coal placed in the vicinity of the downstream miter gates remained in place during an emptying operation at maximum lift conditions (Photo 8). The coal was not adequately flushed with maximum lift conditions even when steady flow through the emptying system was maintained for 1 hr (prototype). Photos 9 and 10 show flow conditions associated with the type 5 design outlet area during 4-min normal and single-valve emptying operations for maximum and minimum lift conditions.

## Type 6 Design Outlet Area

22. Vertical walls and a 1V on 5H slope, sloping upward away from the port faces, were placed in the pit of the type 2 design discharge manifold to redirect the jets issuing from the manifold. This design was designated the type 6 design outlet area and is shown in Plate 11. The vertical walls were angled in an attempt to create a circular flow pattern that would aid in flushing out sediment in the downstream approach during emptying operations. Observations of dye patterns indicated that the currents were in a generally clockwise rotation. During emptying operations at maximum lift conditions, the coal located close to the lock walls was displaced and then deposited in the vicinity of the center line of the approach near the miter gates. Although the flushing capability was improved over the type 5 design outlet area, this design did not remove coal placed near the lower miter gates.

## Type 7 Design Outlet Area

23. The last three downstream ports of the type 2 design discharge manifold were plugged to increase the discharging velocities from the remaining ports. This manifold, designated the type 3 design discharge manifold, had a port-to-culvert-area ratio of 1.09 (port area of 157.5 sq ft per 12- by 12-ft culvert). Steady-flow tests were made to determine the flow distribution in the five-port manifold. Flow out of the type 3 design discharge manifold was more evenly distributed than the type 2 design discharge manifold even though the interior of the manifold was not reconstructed to provide appropriately streamlined boundaries. Test results are shown in Plate 12.

24. Modifications were made to the outlet area associated with the type 3 design discharge manifold. These modifications, designated the type 7 design outlet area (Plate 13), included the use of vertical walls installed in a similar manner to that used in the type 6 design outlet area. Even though the type 7 design outlet area resulted in increased currents during emptying, little difference was observed between the type 6 and type 7 designs in removing the coal from the vicinity of the miter gates.

### Type 8 Design Outlet Area

25. The type 8 design outlet area (Plate 14) consisted of the type 3 design discharge manifold with a 1V on 5H slope and vertical walls placed in the manifold pit. The vertical walls were angled in such a manner that two eddies (one clockwise and one counterclockwise) would form during emptying operations. Coal located in the vicinity of the miter gates was moved from the center line of the approach during emptying operations at maximum lift conditions, but was deposited near the gate pintles. Modifications to the outlet areas associated with the sidewall manifolds never resulted in coal being flushed from the miter gate vicinity for maximum lift conditions when the manifold was located with the upstream edge at sta 8+35.

### Type 9 Design Outlet Area

26. The type 9 design outlet area (Figure 10, Plate 15) consisted of the type 2 design discharge manifold moved closer to the miter gates. The upstream edge of the upstream port of the manifold was relocated to sta 8+00 (15 ft downstream from the center line of the pintle).

27. A dry-bed photograph of the type 9 design outlet area with coal placed near the miter gates is shown in Photo 11a. Photo 11b, which shows the coal remaining after one emptying operation at maximum lift conditions, illustrates that a large percentage of the coal was removed. However, the coal was not adequately flushed during an emptying operation with minimum lift even when steady flow through the emptying system was maintained for 1 hr (prototype) as shown in Photos 11c and 11d.

### Type 10 Design Outlet Area

28. To improve the flushing capability for minimum lift conditions, a 1V on 5H slope, sloping upward away from the face of the ports, was placed in the pit of the type 2 design discharge manifold (type 10 design outlet area, Figure 11, Plate 16). For maximum lift conditions, most of the coal was removed from the vicinity of the miter gates during one emptying operation. The coal was not removed during one emptying operation with minimum lift conditions. Some coal even remained in the vicinity of the miter gate when

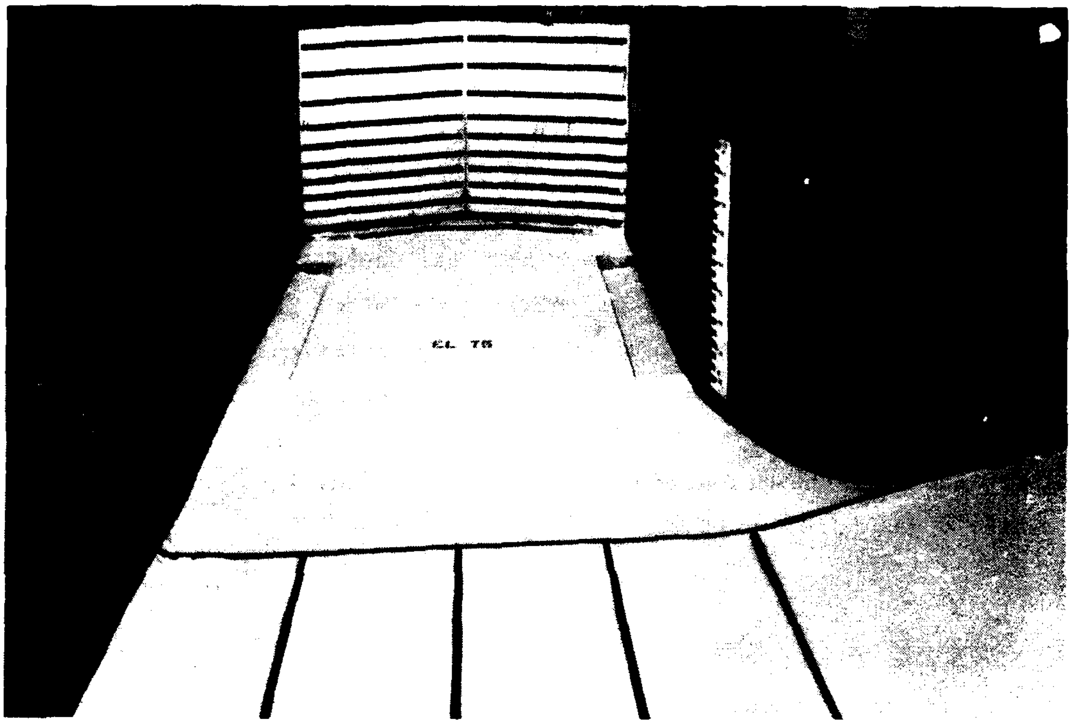


Figure 10. Type 9 design outlet area

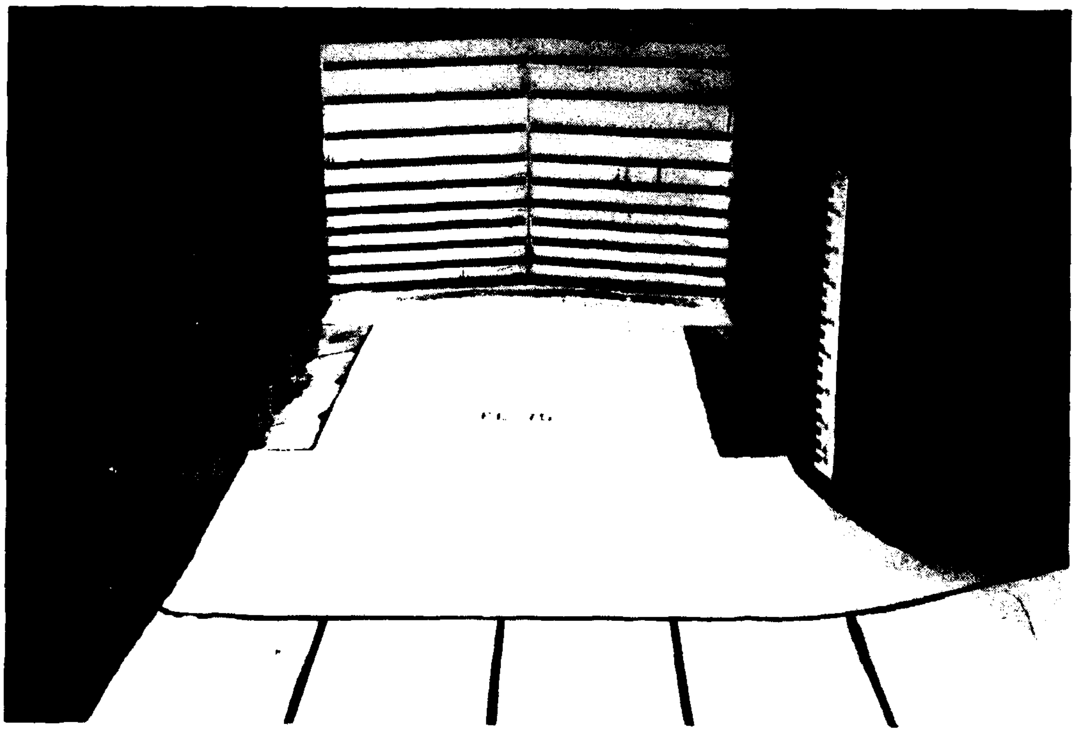


Figure 11. Type 10 design outlet area

steady flow through the emptying system was maintained for 1 hr (prototype). Results of tests conducted with the type 10 design outlet area are shown in Photo 12. Photos 13 and 14 are of flow conditions during emptying operations with the type 10 design outlet area.

## Type 11 Design Outlet Area

29. The type 11 design outlet area (Figure 12, Plate 17) consisted of the type 3 design discharge manifold (five-port sidewall manifold) with a 1V on 5H slope placed in the manifold pit. The type 11 design outlet area resulted in the removal of virtually all the coal placed in the vicinity of the lower miter gates for the condition of maximum lift (Photo 15a and 15b). Not much coal was removed during one emptying operation for minimum lift condition (Photo 15c). However, the coal was adequately flushed with minimum lift conditions when steady flow through the emptying system was maintained for 1 hr (prototype), as shown in Photo 15d. Photos 16 and 17 show flow conditions during emptying operations with the type 11 design outlet area.

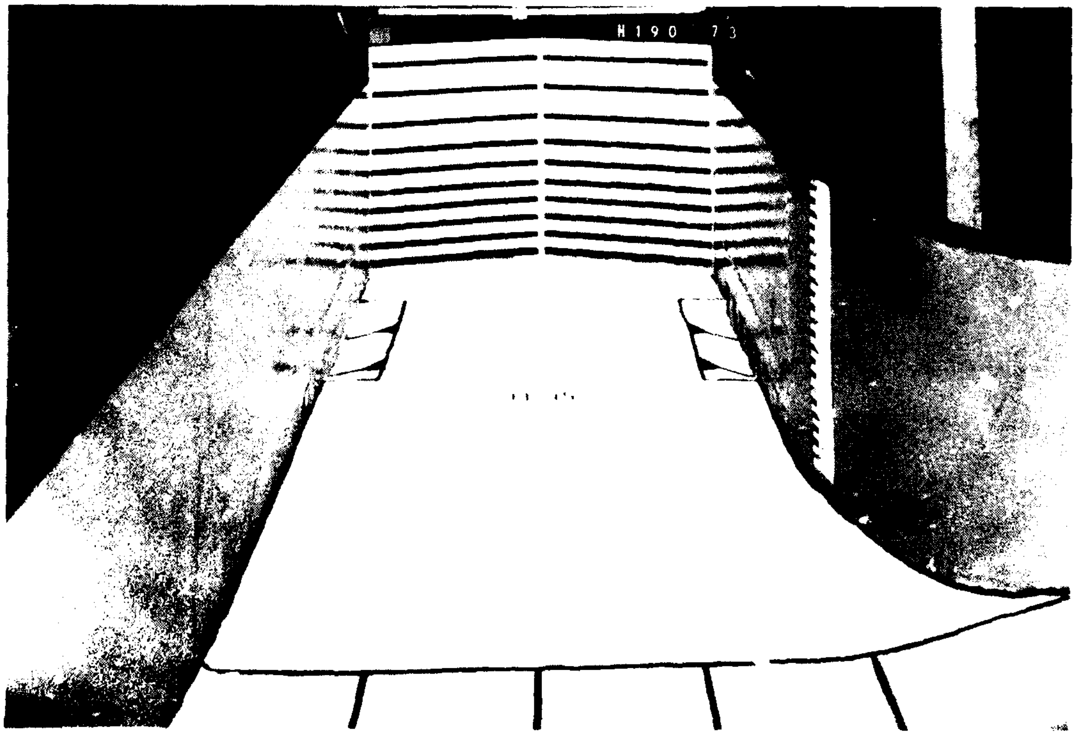



Figure 12. Type 11 design outlet area

## Type 12 Design Outlet Area

30. At this point in the testing program, the US Army Engineer District, Vicksburg, requested that tests be conducted with the type 3 design discharge manifold shifted downstream 9 ft. This shift of 9 ft allowed space for the bulkhead recess. The upstream edge of the upstream port of the type 3 design discharge manifold was located at sta 8+09. The associated outlet area (type 12 design outlet area, Figure 13, Plate 18) was similar to the type 11 design outlet area except shifted downstream 9 ft.

31. The type 12 design outlet area resulted in the removal of the majority of coal placed in the vicinity of the miter gates for the condition of maximum lift. Essentially no coal was removed during one emptying operation for minimum lift. However, a majority of the coal was flushed from the vicinity of the gates for minimum lift conditions when steady flow through the emptying system was maintained for 1 hr (prototype). Results of tests conducted with the type 12 design outlet area are shown in Photo 18.

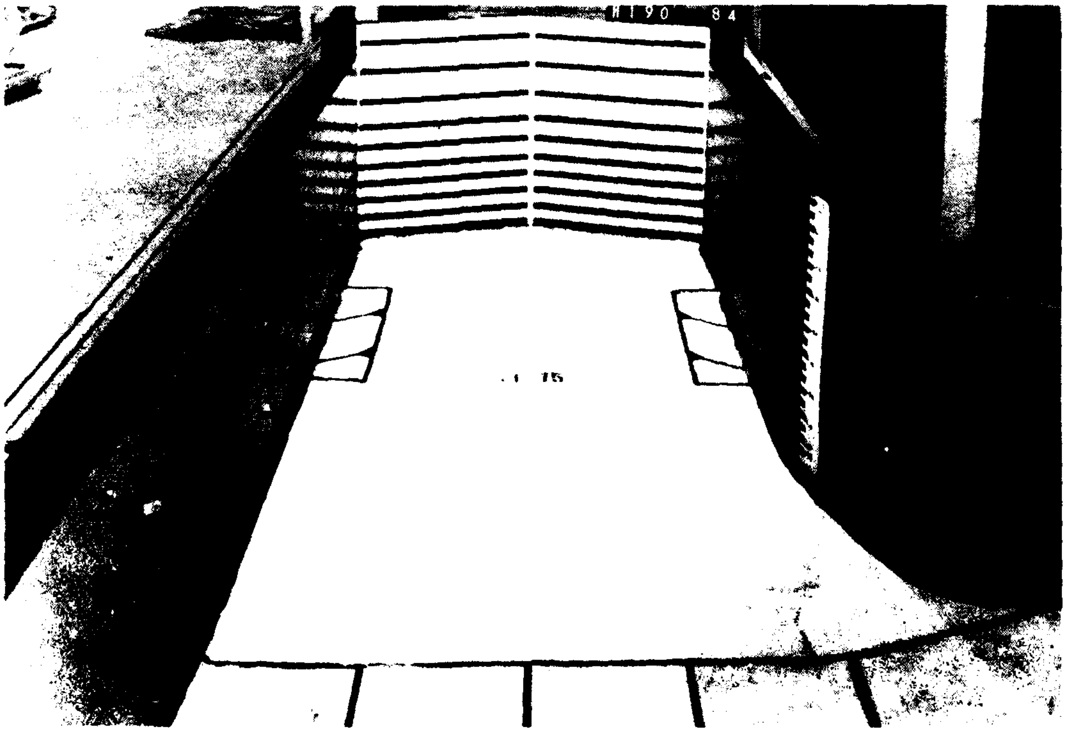


Figure 13. Type 12 design outlet area

## Type 13 Design Outlet Area

32. Additional tests were conducted with the type 3 design discharge manifold shifted downstream such that the upstream edge of the upstream port was located at sta 8+18. This relocation of the manifold, designated the type 13 design outlet area (Figure 14, Plate 19), was tested because of concerns of the Vicksburg District with regard to the distance between the upstream port and miter gate pintles.

33. Test results with the type 13 design indicated that coal placed in the vicinity of the downstream miter gates was not adequately flushed during emptying operations. The type 13 design also resulted in adverse flow conditions in the vicinity of the miter gates. During emptying, bulking at the manifold created waves that traveled upstream, hitting the miter gates. These waves could result in additional loads being placed on the downstream side of the miter gates. Results of tests conducted with the type 13 design outlet area are shown in Photo 19. Photos 20 and 21 show flow conditions during emptying operations with the type 13 design outlet area.

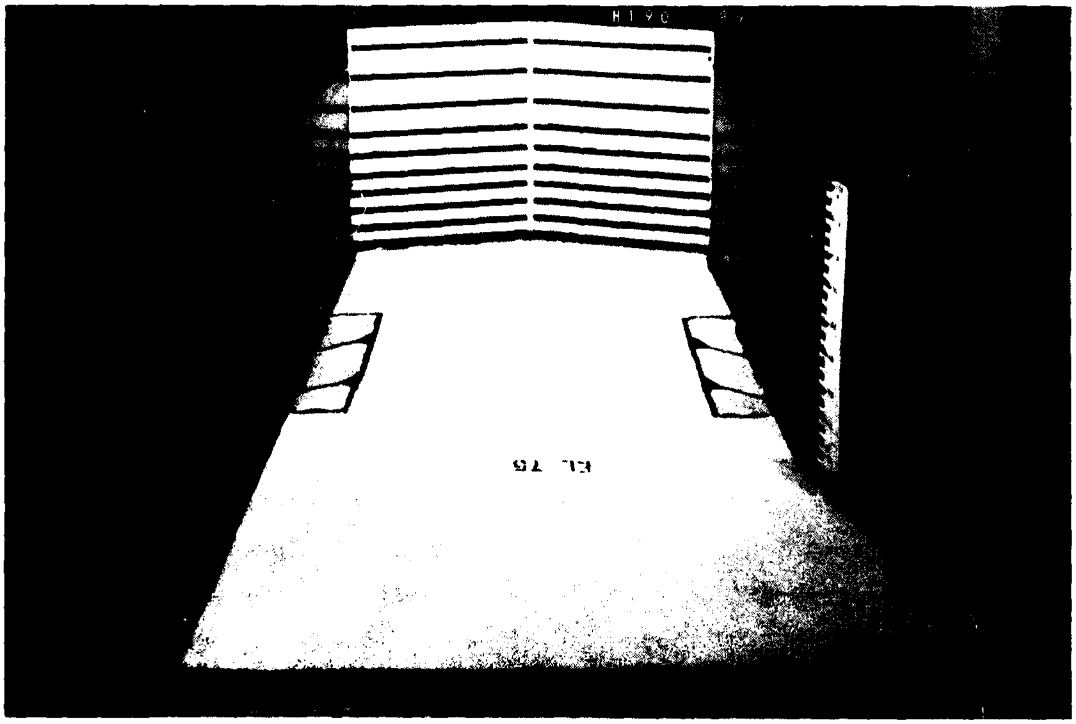


Figure 14. Type 13 design outlet area

## PART IV: SUMMARY AND RECOMMENDATIONS

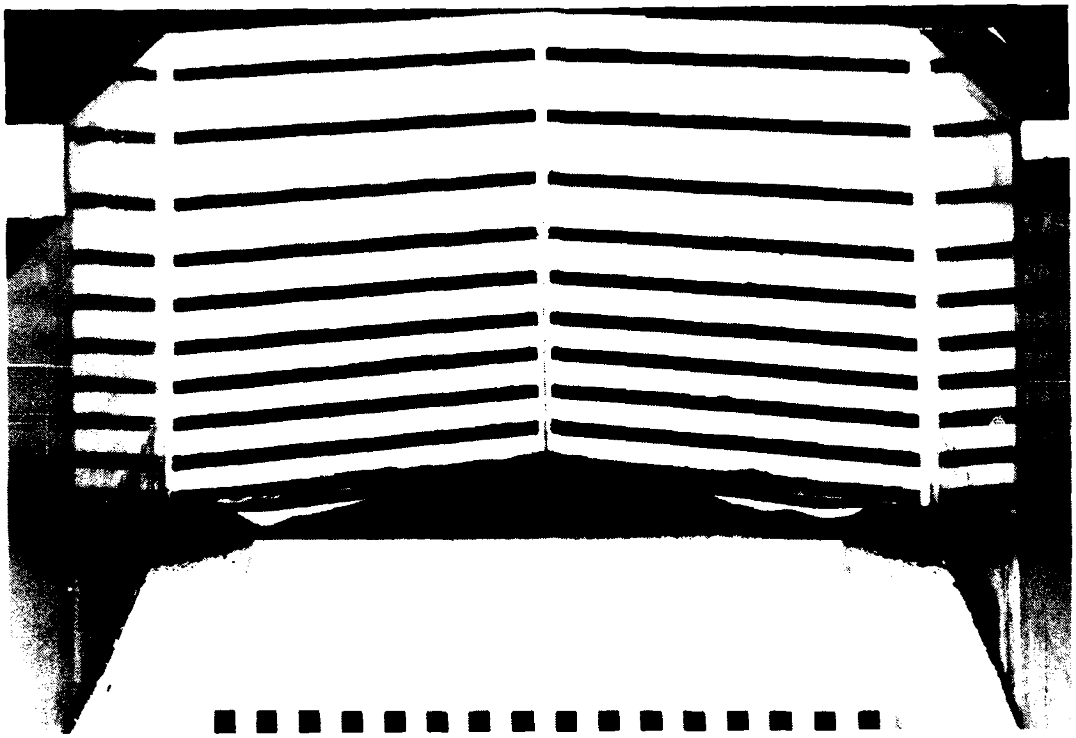
34. Red River Lock 1 experienced problems associated with sediment accumulation near the lower miter gates. This sediment accumulation resulted in the structural damage of a miter gate pintle during gate closure. The 1:25-scale model tests were conducted to determine if modifications to the conventional low-lift lock emptying system would eliminate or reduce the amount of sediment deposited in the vicinity of the lower miter gates.

35. Two totally different manifold designs were evaluated to determine the performance of each after one emptying operation for maximum and minimum lift conditions, and during steady flow with minimum lift conditions with the emptying valves fully opened. To determine qualitatively the effectiveness of various outlet designs, crushed coal was placed in the vicinity of the lower miter gates and the amount of coal displaced during emptying operations was used as a comparison.

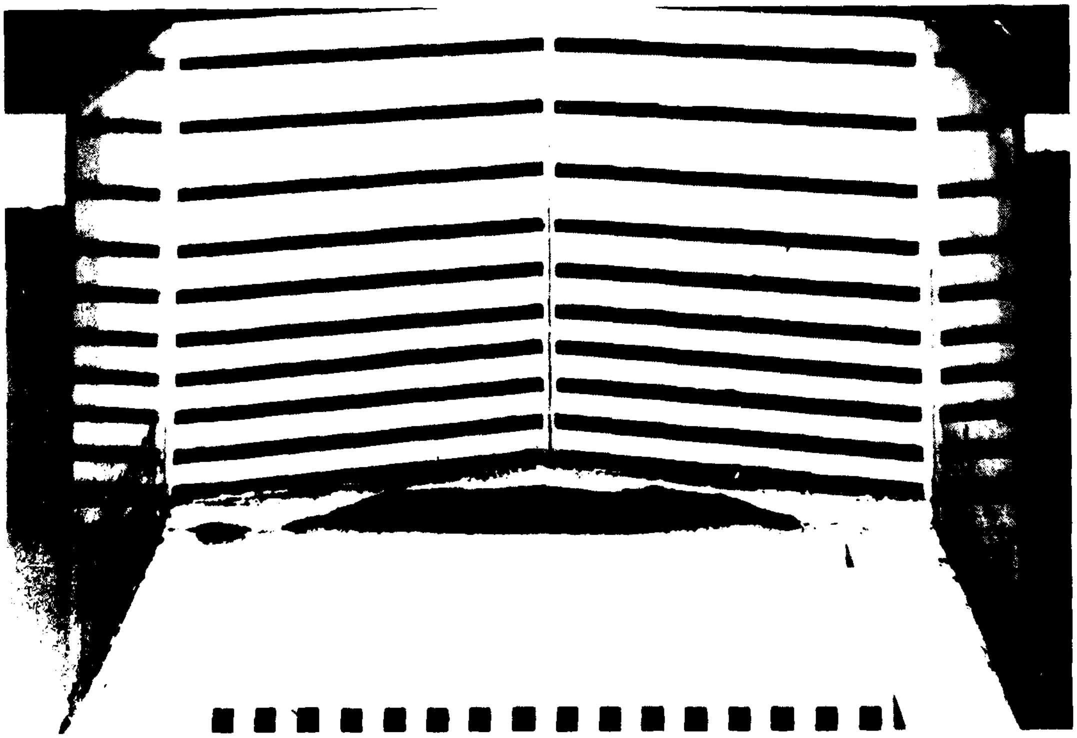
36. The first manifold tested was a unique design developed at WES that was specifically designed to flush sediment from the area near the lower miter gates while maintaining lock emptying efficiency. This manifold issued jets in both the upstream and downstream directions (paragraph 10). It was not practical to modify existing locks to include this type of manifold, but it could be incorporated into the design of locks to be constructed in the future. From the various modifications tested with this manifold design, the type 4 design outlet area, which included baffle blocks (paragraph 16), provided the best overall results. Virtually all of the coal was removed from the vicinity of the miter gates after one emptying operation with maximum lift conditions and after steady-flow conditions were maintained for 30 min (prototype) with minimum lift conditions. None of the designs tested removed all of the coal after one emptying operation with minimum lift conditions.

37. The types 11 and 12 design outlet areas (paragraphs 29 and 30, respectively), which incorporated a more standardized sidewall manifold design with recessed pits in front of the manifold ports, also produced satisfactory results. The majority of coal was flushed out with one emptying operation at maximum lift conditions and when steady-flow conditions were maintained for 1 hr (prototype) with minimum lift conditions. Again, none of the designs tested removed all of the coal during one emptying operation with minimum lift conditions. However, the type 12 design outlet area is recommended for the

prototype over the type 11 design outlet area because of structural considerations. Since the manifold ports are located further downstream from the miter gates in the type 12 design, it provides more space for the bulkhead recess. However, even the type 12 design outlet area would require a significant structural design effort.

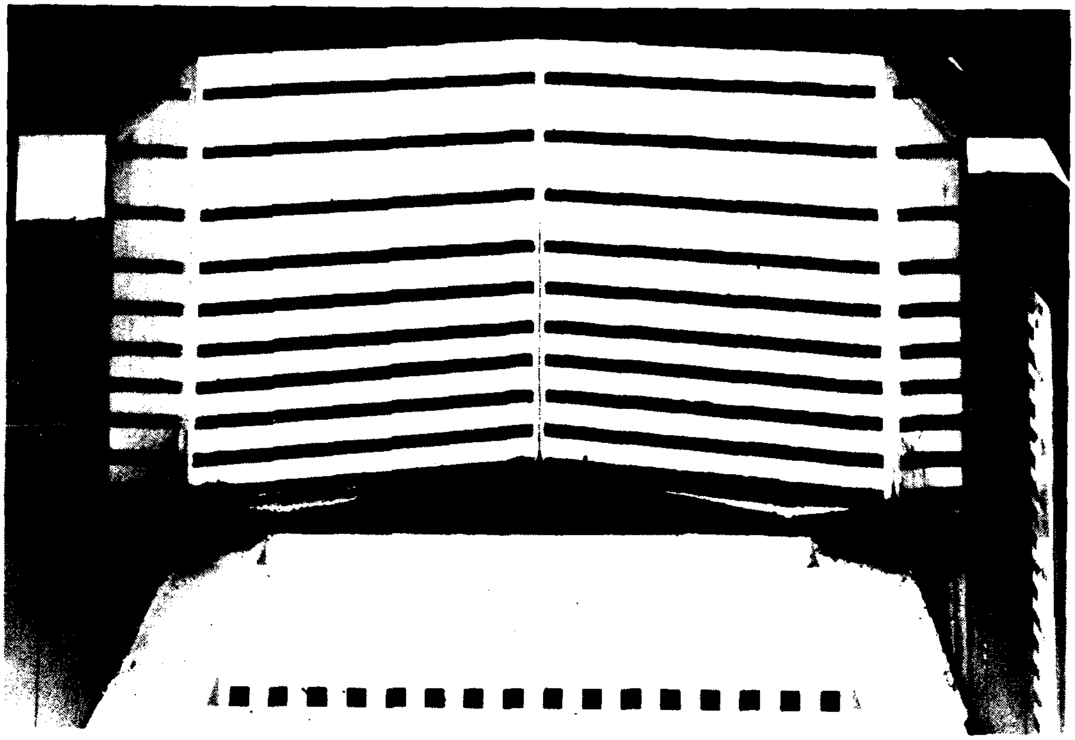


a. Coal placed near miter gates

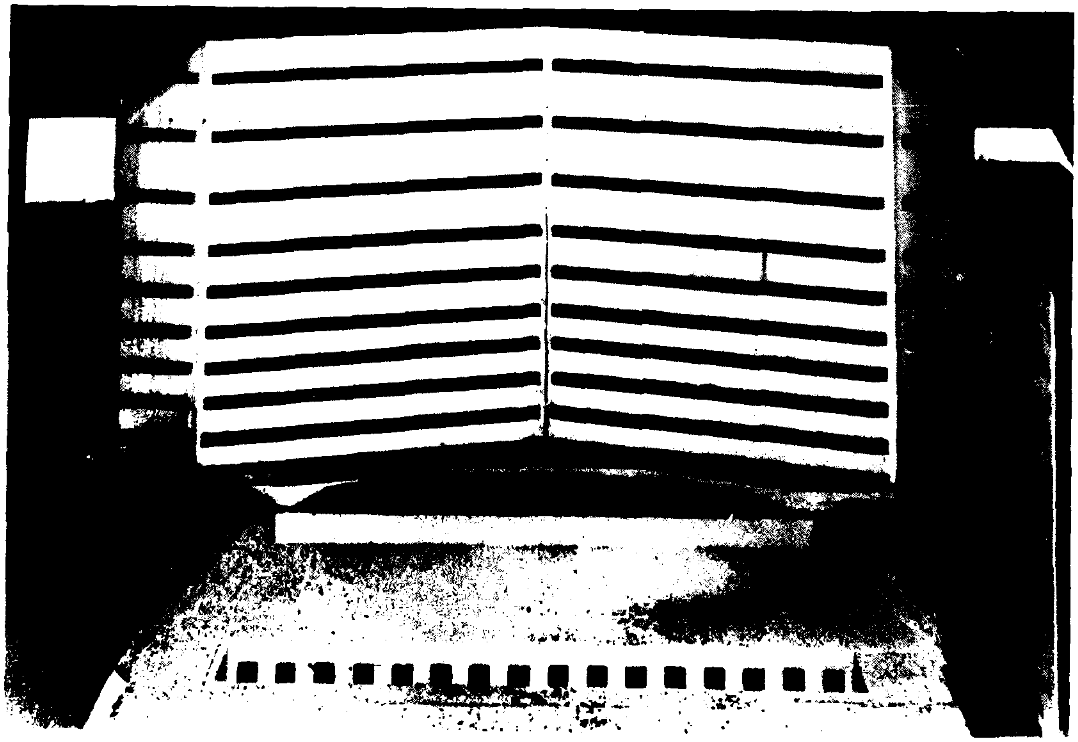


b. Coal remaining after one emptying operation at maximum lift

Photo 1. Type 1 (original) design outlet area (Continued)

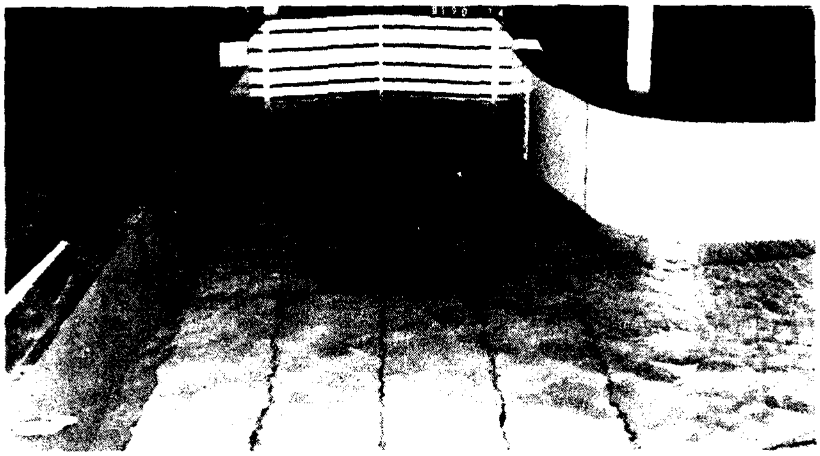


c. Coal remaining after one emptying operation at minimum lift

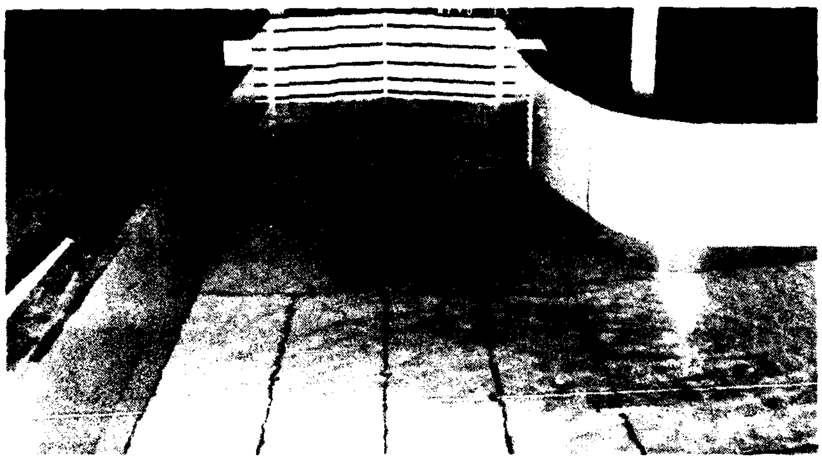


d. Coal remaining after 1 hr of steady flow at minimum lift

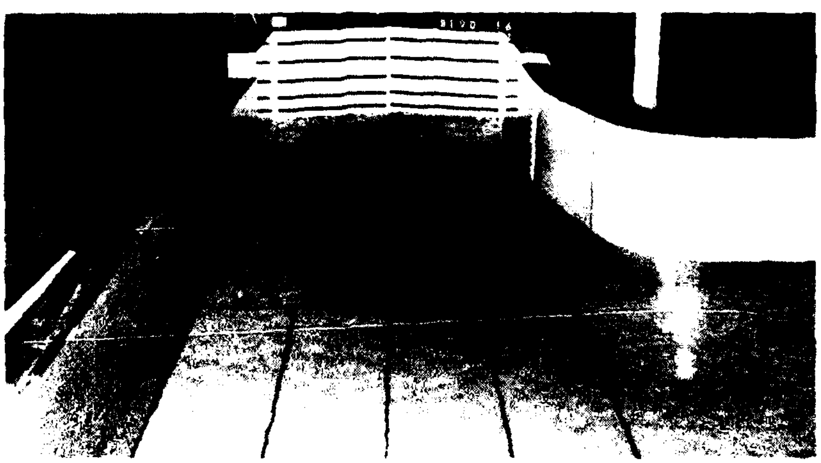
Photo 1. (Concluded)



a. Normal valve

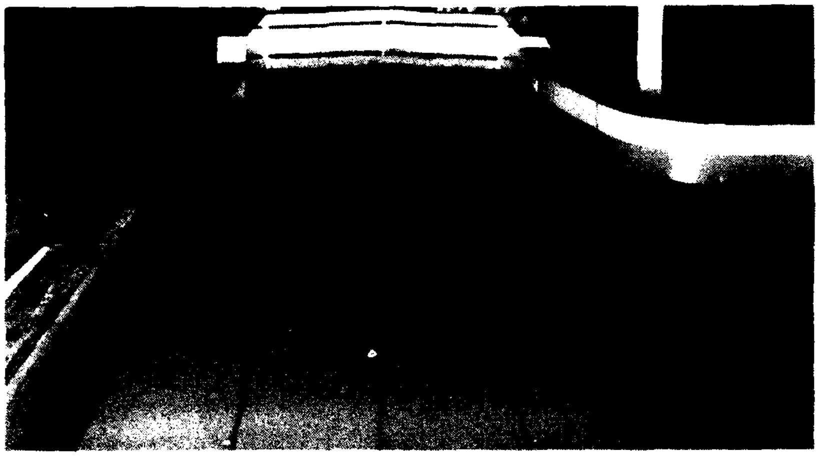


b. Single valve (left)

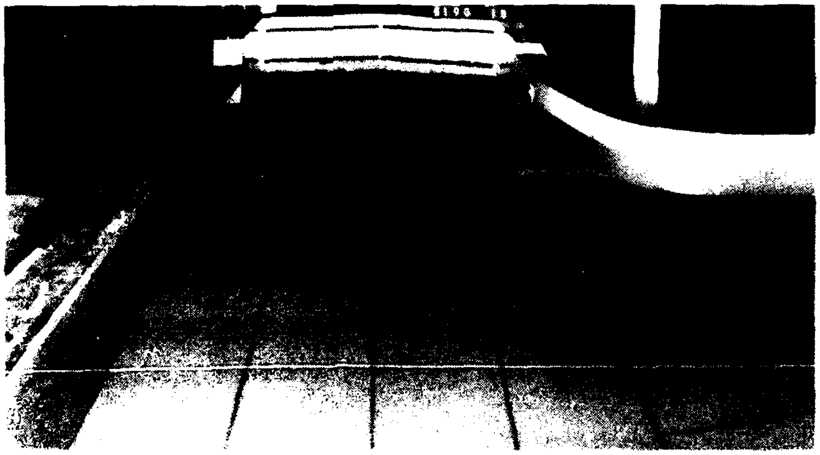


c. Single valve (right)

Photo 2. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 1 (original) design outlet area; initial head 25 ft; initial lock chamber el 120; lower pool el 95



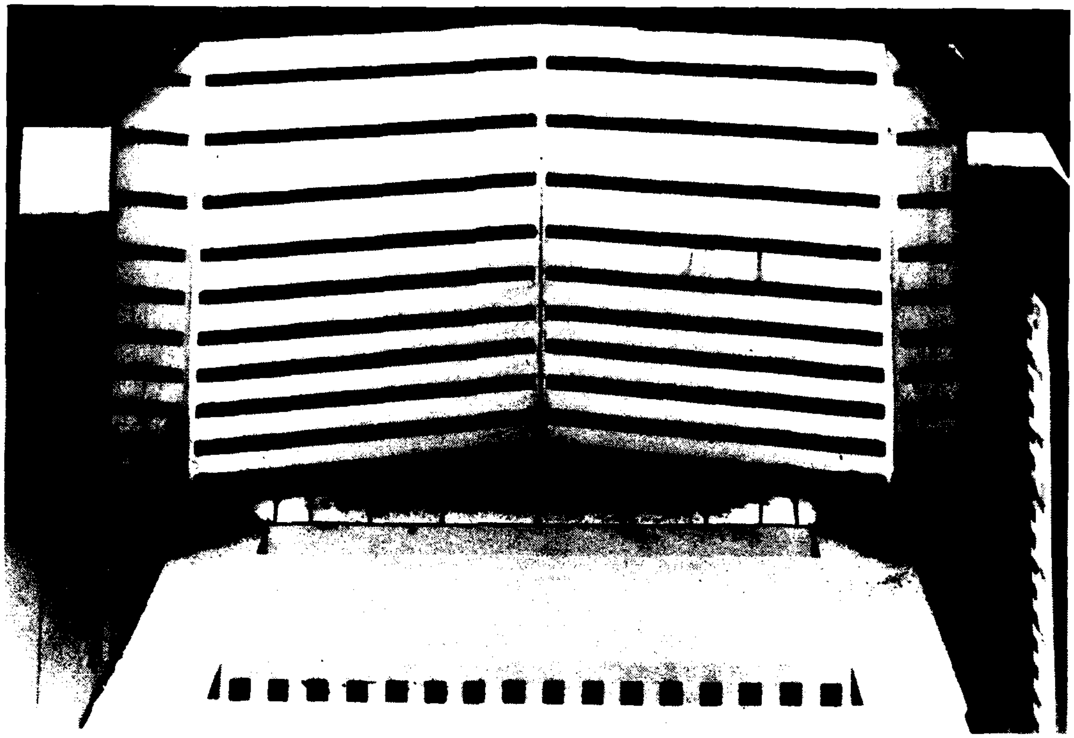
a. Normal valve



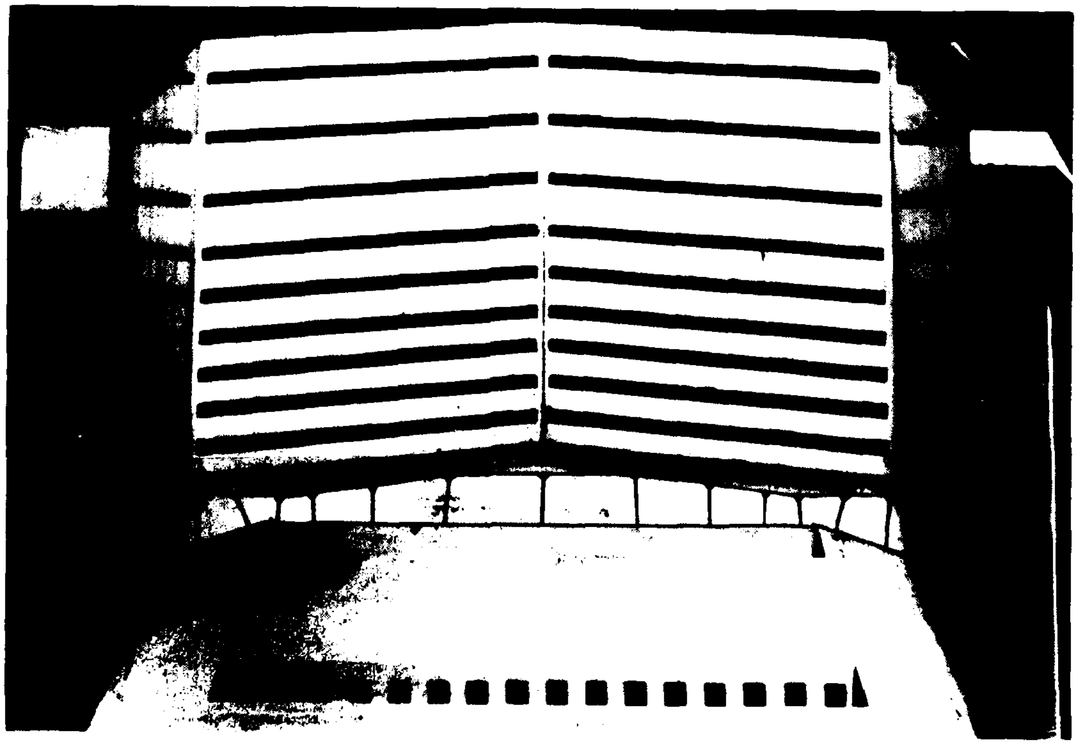
b. Single valve (left)

c. Single valve (right)

Photo 3. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 1 (original) design outlet area; initial head 3.5 ft; initial lock chamber el 121.7; lower pool el 118.2

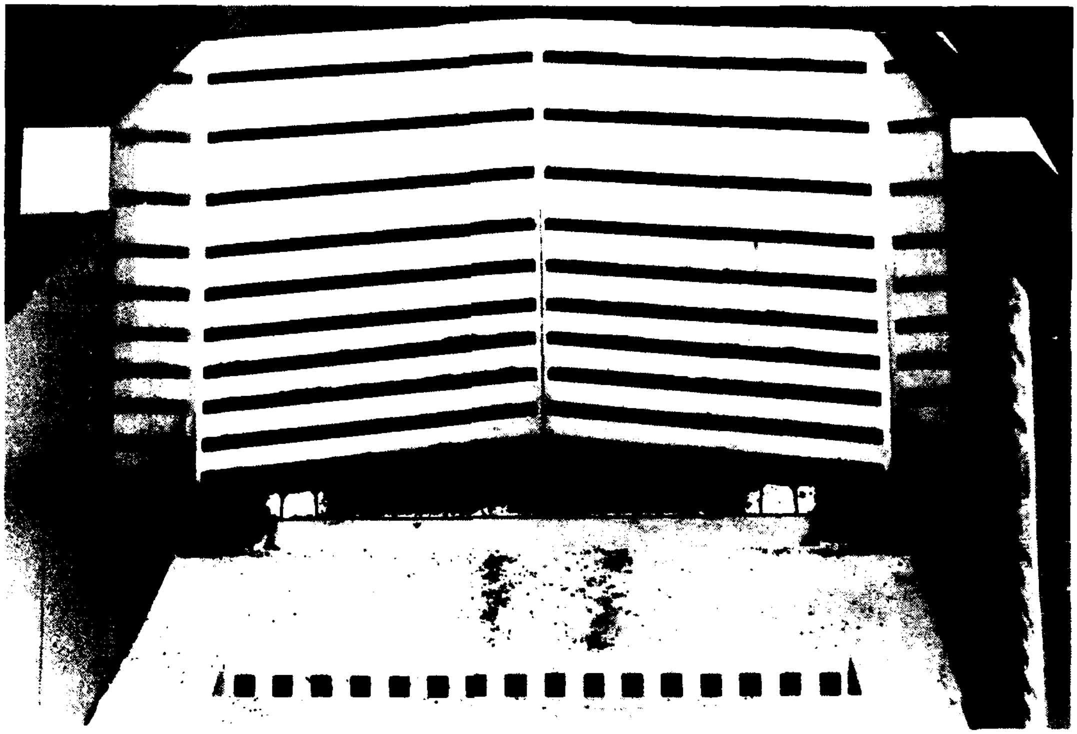


a. Coal placed near miter gates

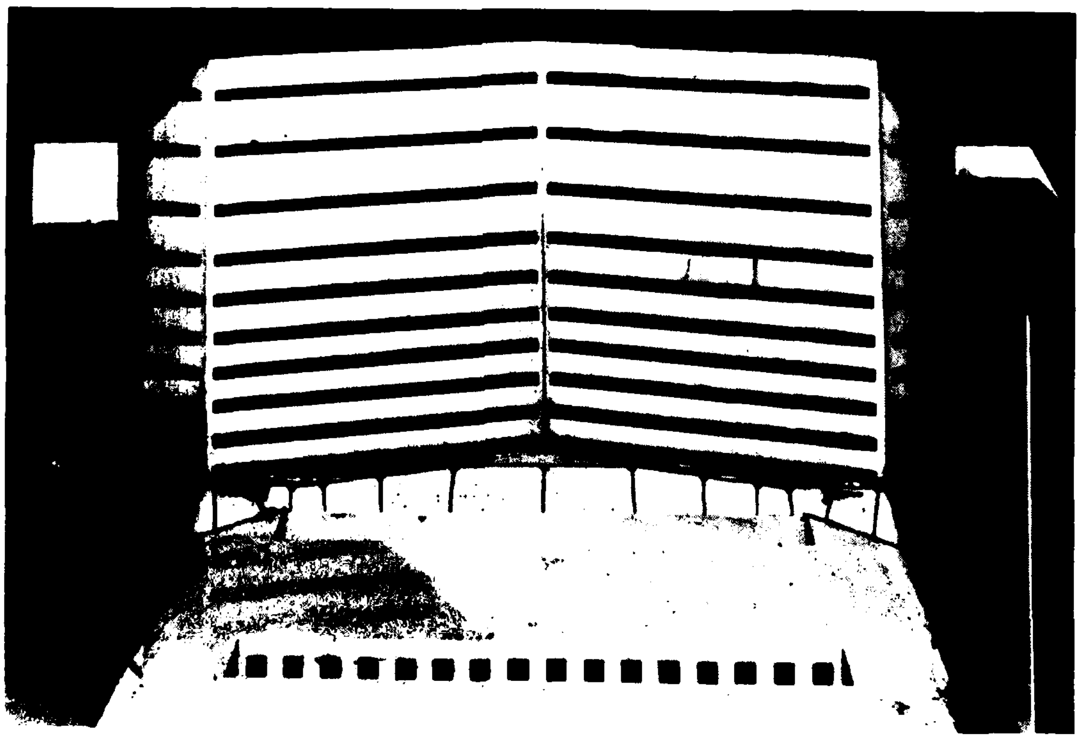


b. Coal remaining after one emptying operation at maximum lift

Photo 4. Type 2 design outlet area (Continued)

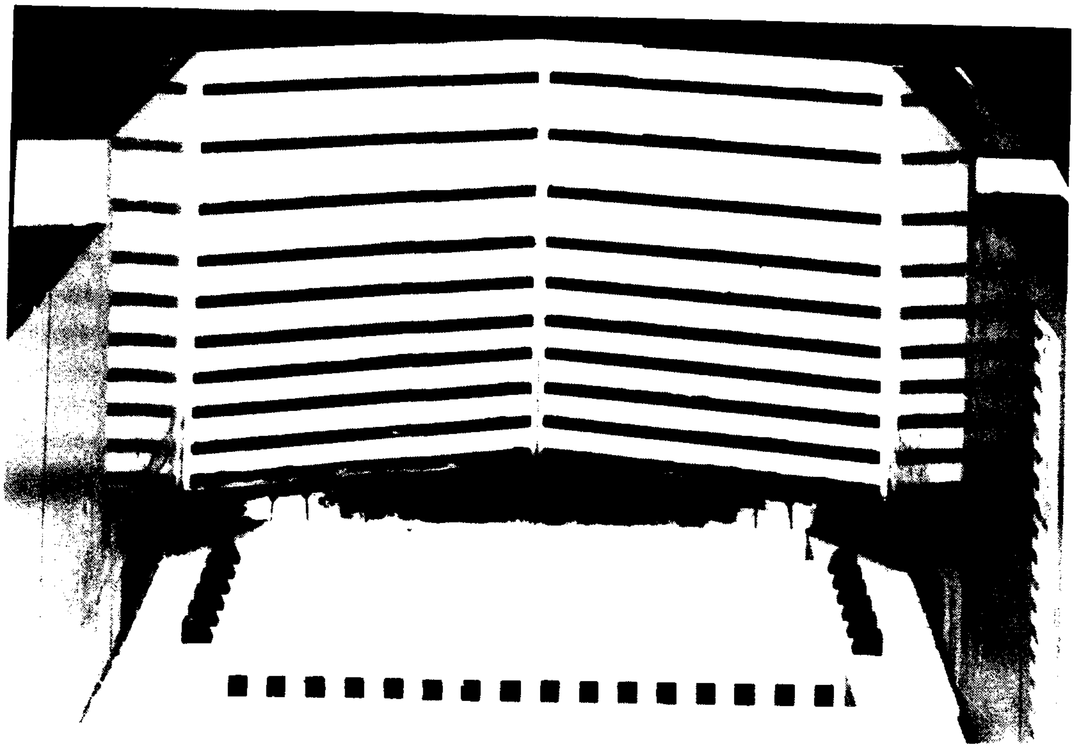


c. Coal remaining after one emptying operation at minimum lift

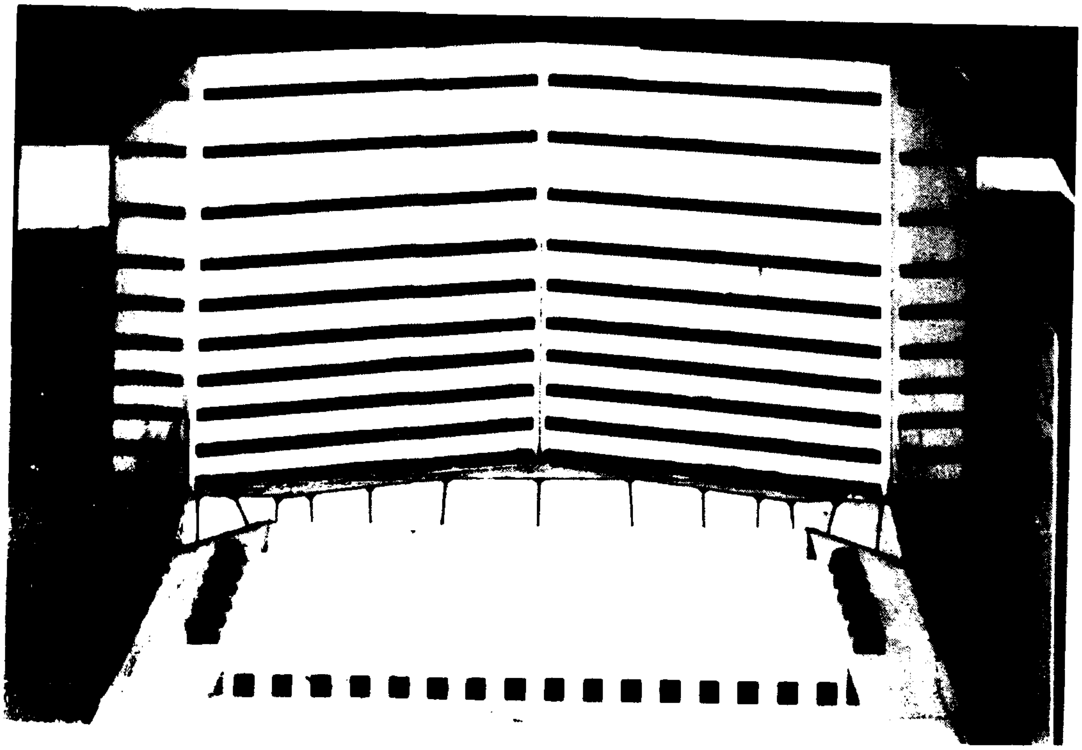


d. Coal remaining after 1 hr of steady flow at minimum lift

Photo 4. (Concluded)

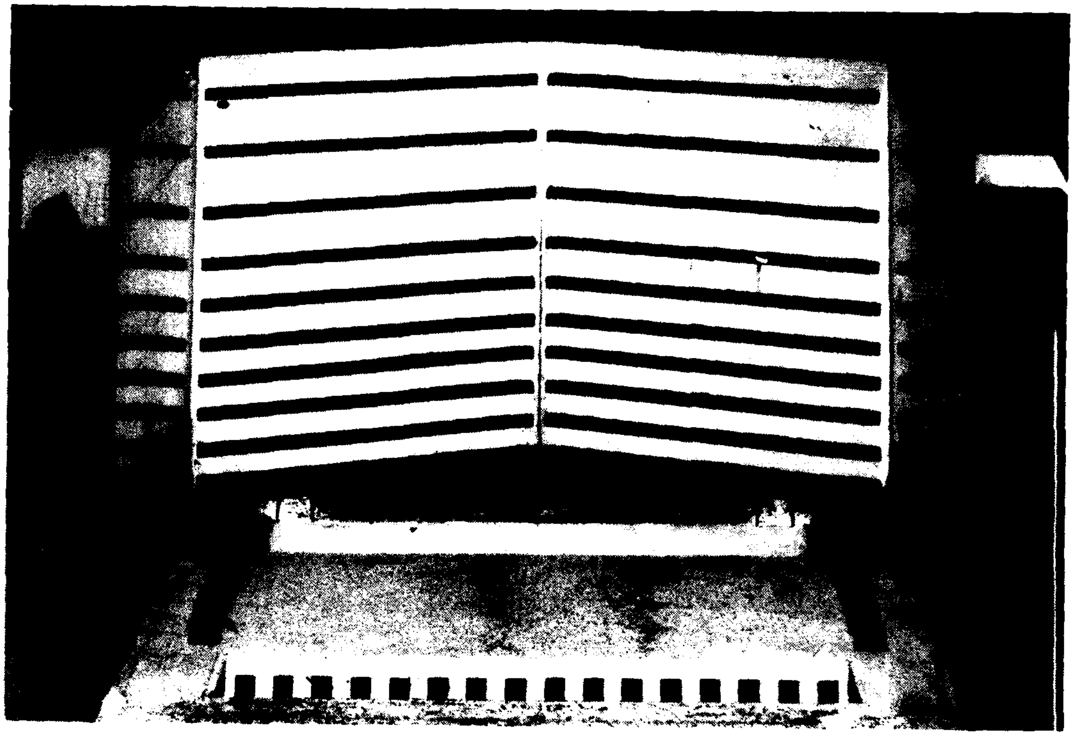


a. Coal placed near miter gates

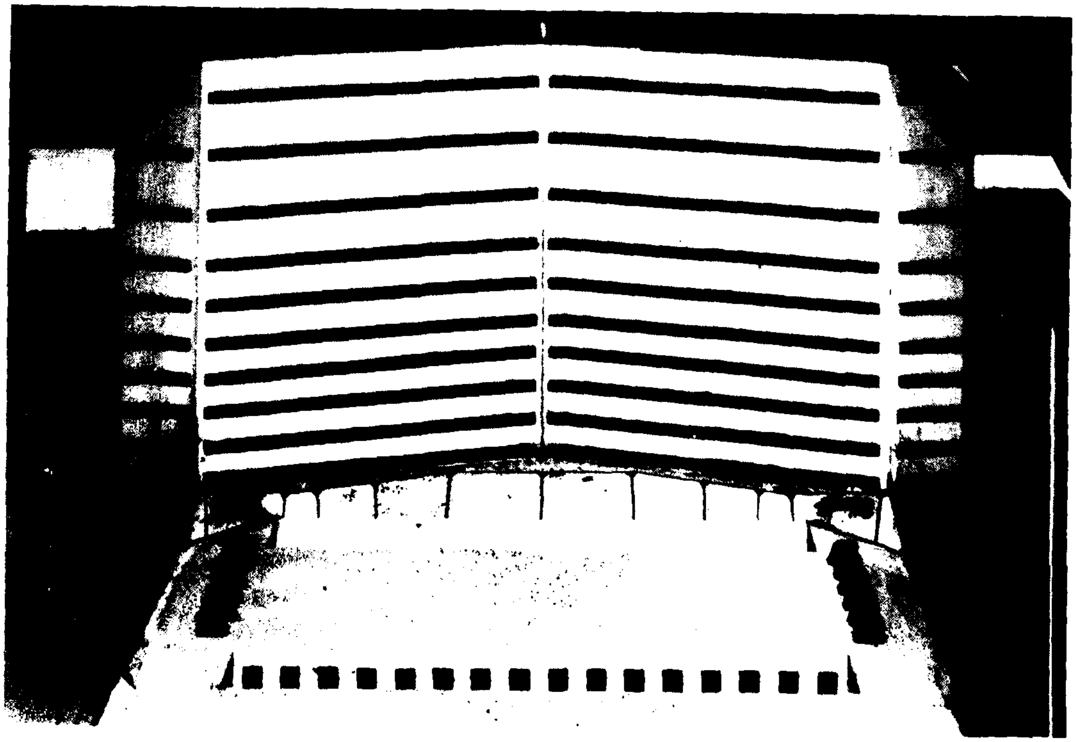


b. Coal remaining after one emptying operation at maximum lift

Photo 5. Type 4 design outlet area (Sheet 1 of 3)

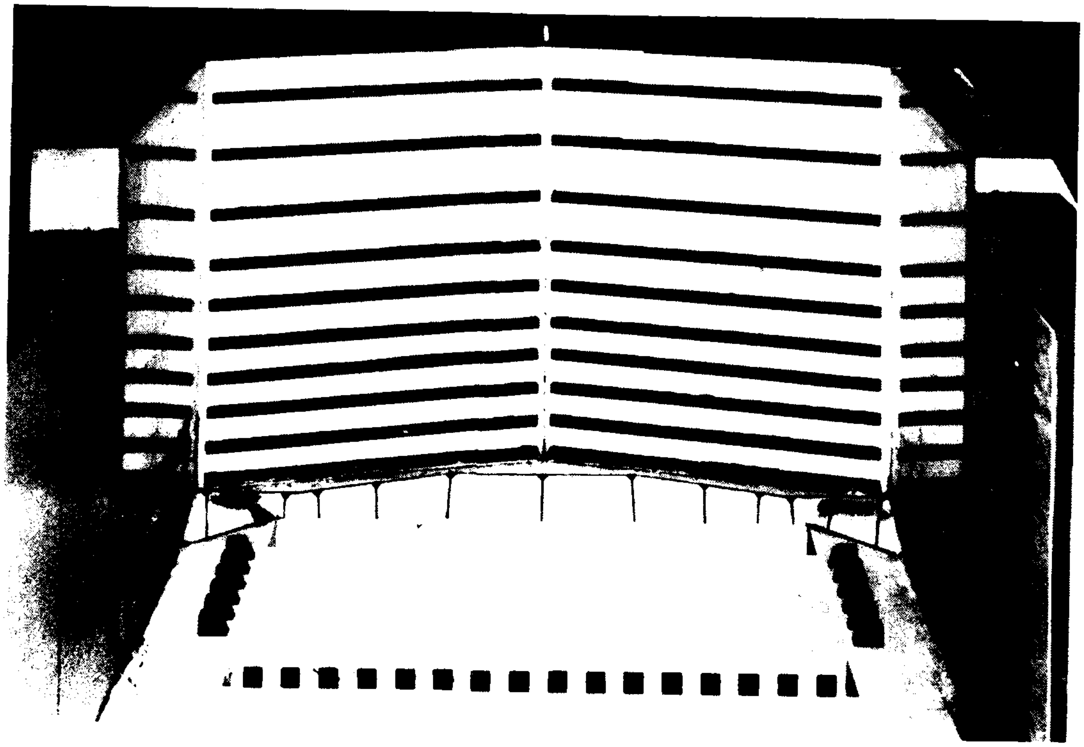


c. Coal remaining after one emptying operation at minimum lift



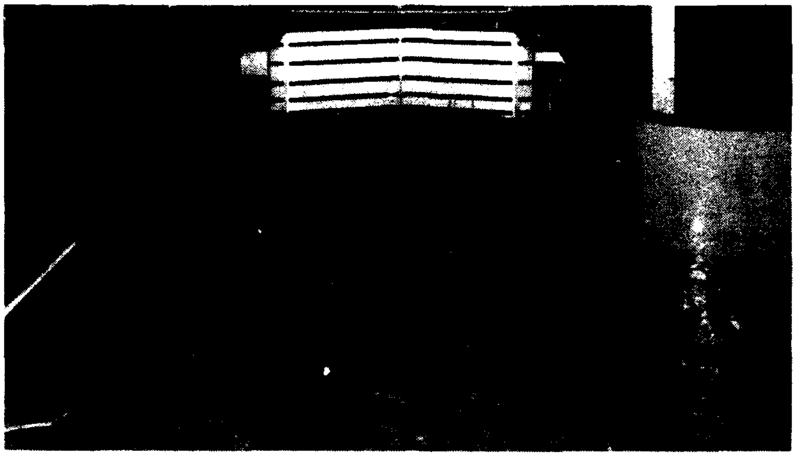
d. Coal remaining after 30 min of steady flow at minimum lift

Photo 5. (Sheet 2 of 3)

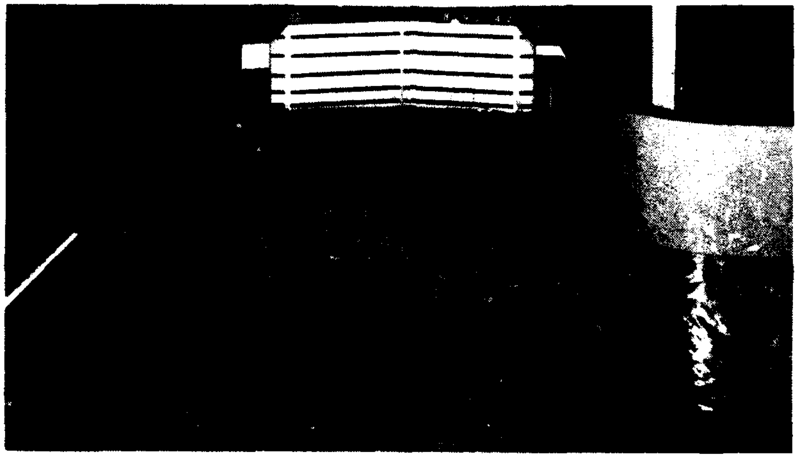


e. Coal remaining after 1 hr of steady flow at minimum lift

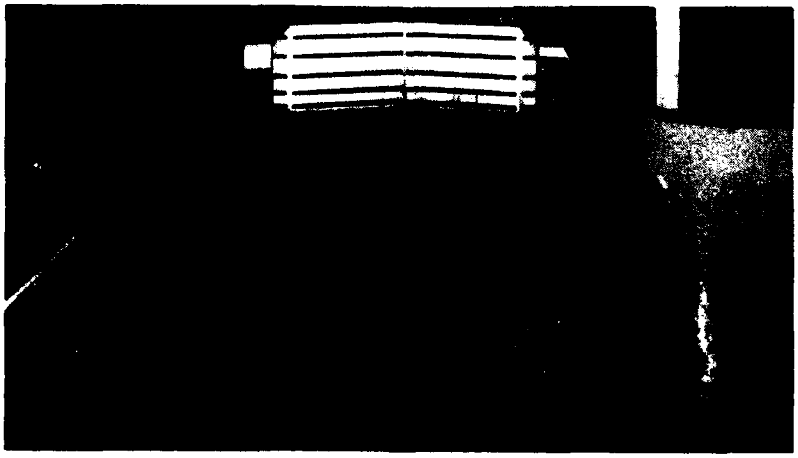
Photo 5. (Sheet 3 of 3)



a. Normal valve

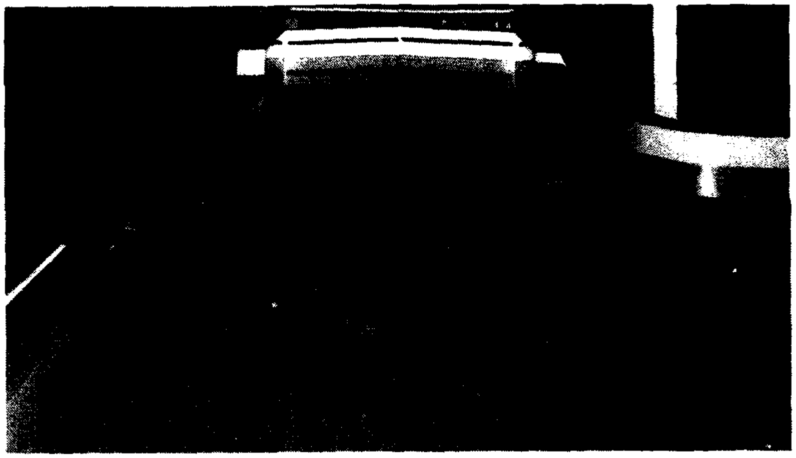


b. Single valve (left)

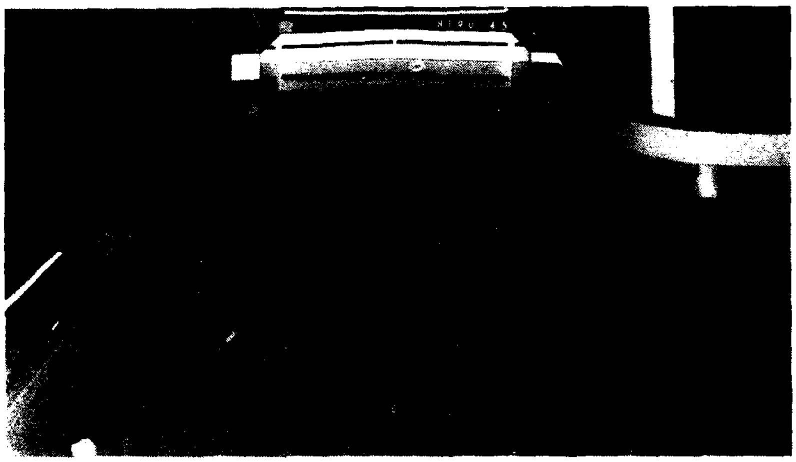


c. Single valve (right)

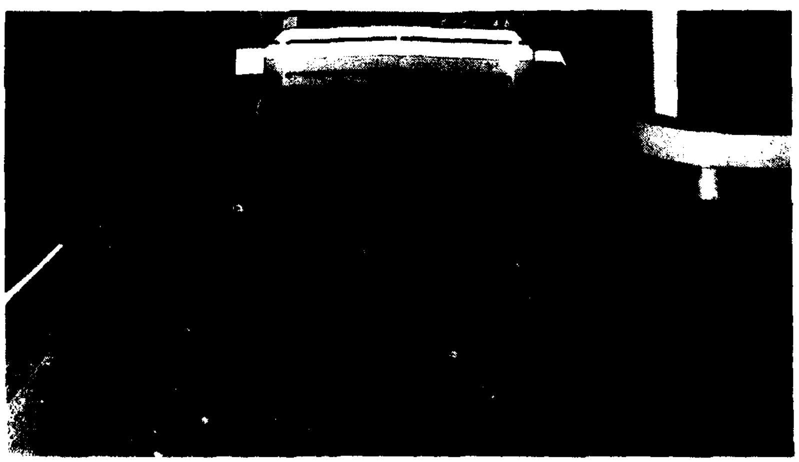
Photo 6. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 4 design outlet area; initial head 25 ft; initial lock chamber el 120; lower pool el 95



a. Normal valve

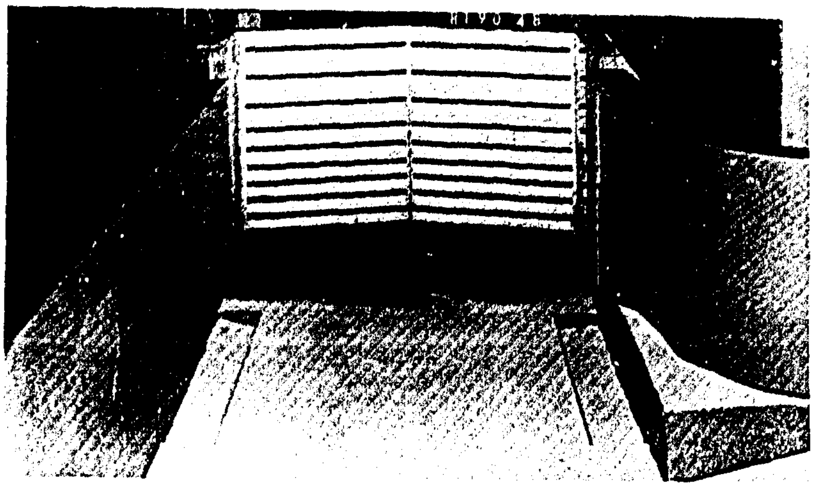


b. Single valve (left)

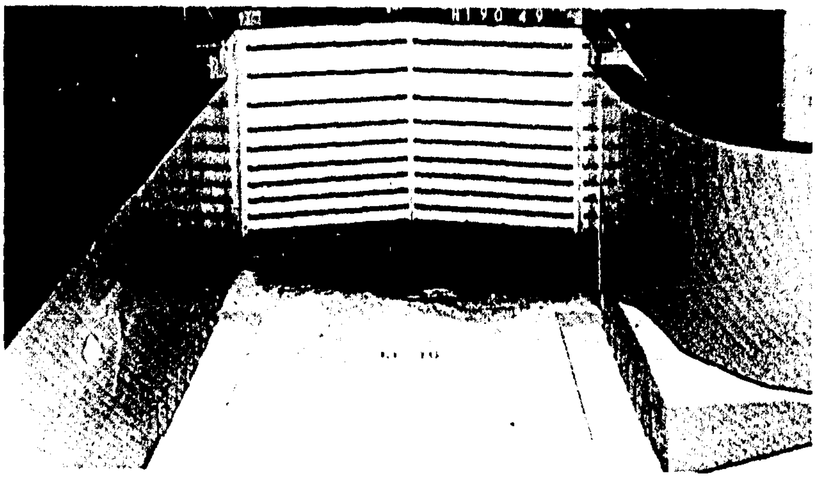


c. Single valve (right)

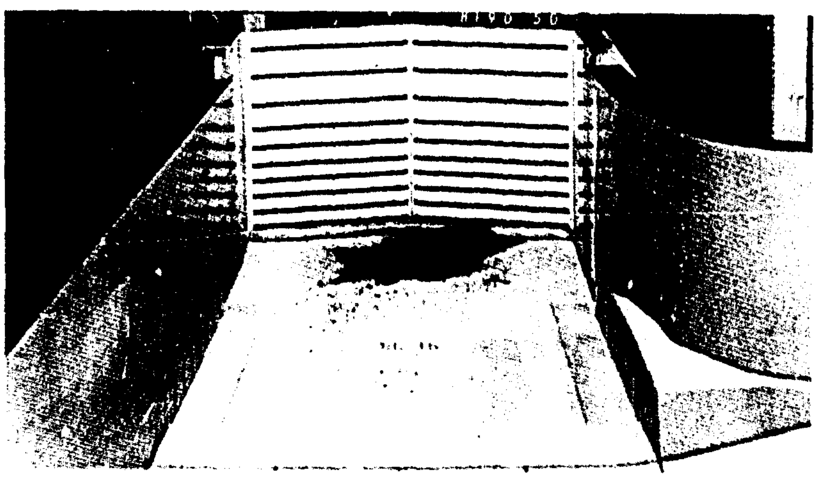
Photo 7. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 4 design outlet area; initial head 3.5 ft; initial lock chamber el 121.7; lower pool el 118.2



a. Coal placed near miter gates

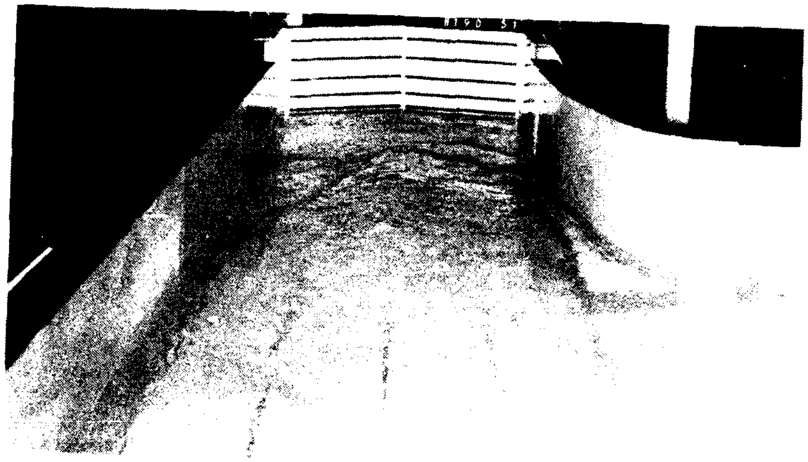


b. Coal remaining after one emptying operation at maximum lift

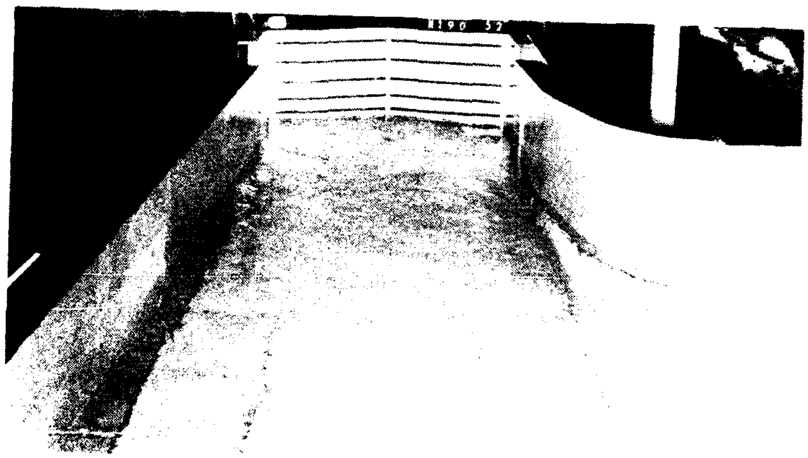


c. Coal remaining after 1 hr of steady flow at maximum lift

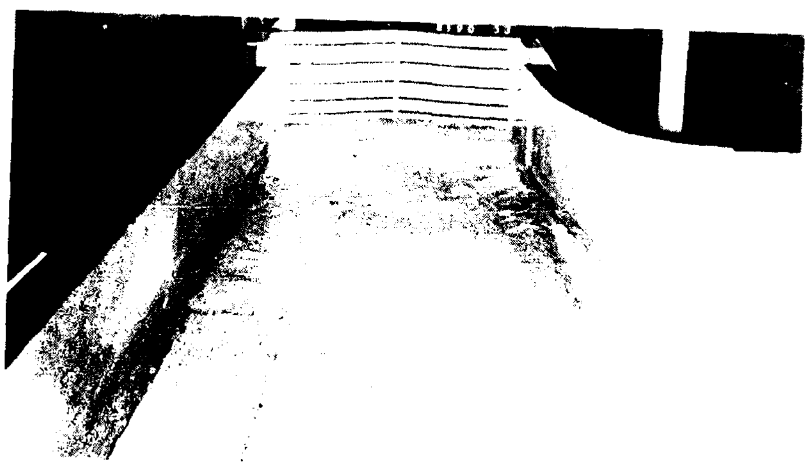
Photo 8. Type 5 design outlet area



a. Normal valve

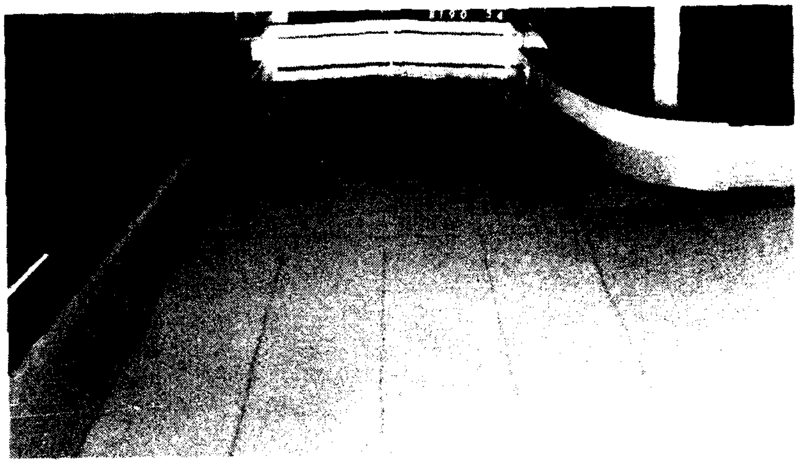


b. Single valve (left)

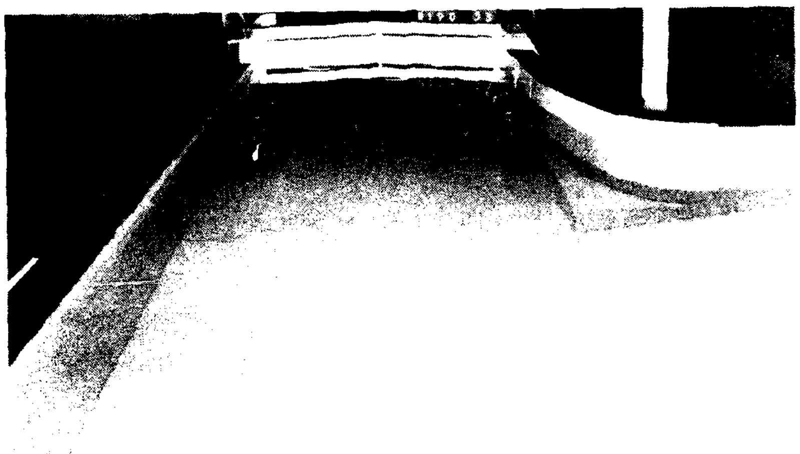


c. Single valve (right)

Photo 9. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 5 design outlet area; initial head 25 ft; initial lock chamber el 120; lower pool el 95



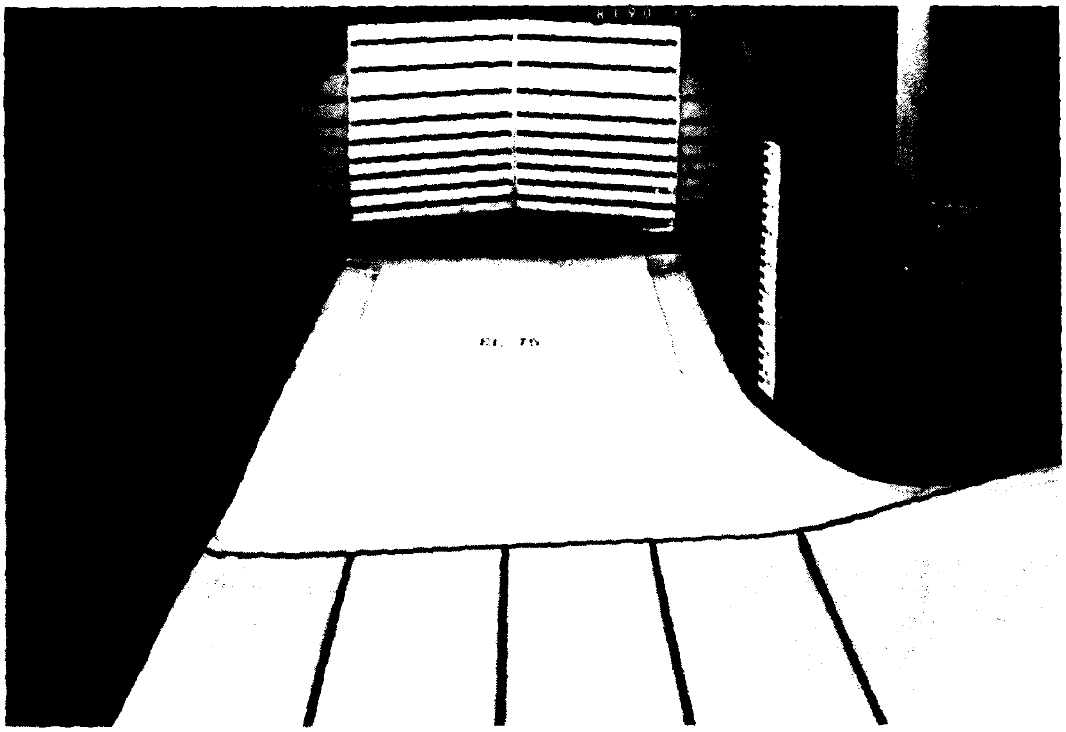
a. Normal valve



b. Single valve (left)

c. Single valve (right)

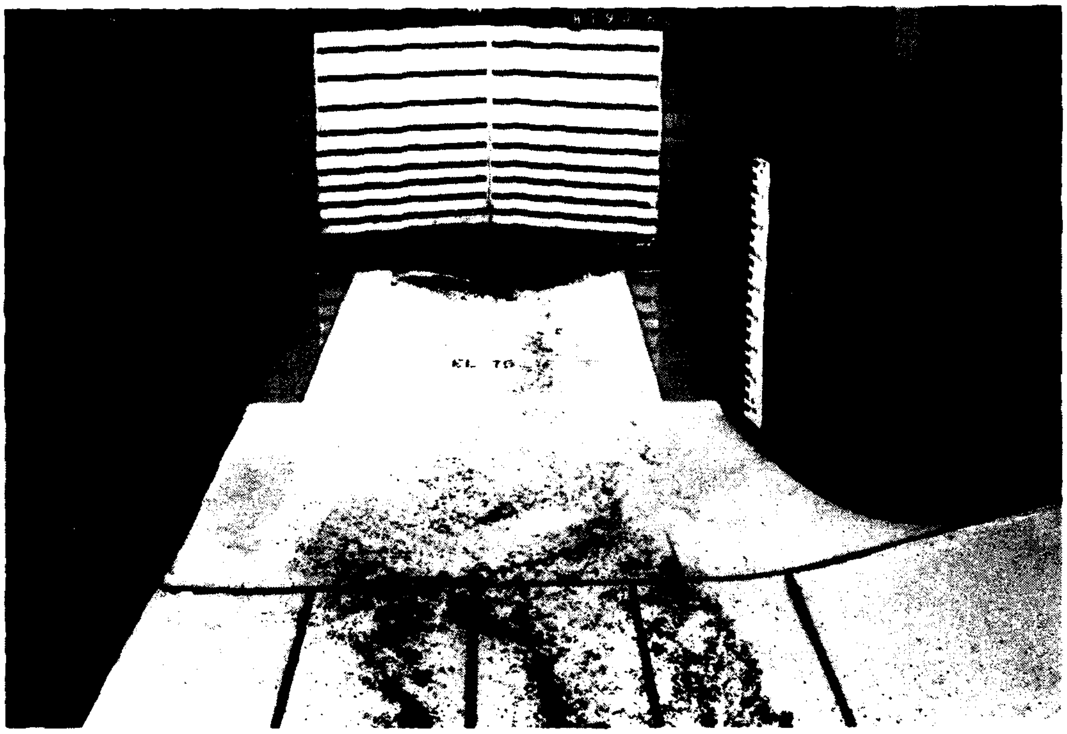
Photo 10. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 5 design outlet area; initial head 3.5 ft; initial lock chamber el 121.7; lower pool el 118.2



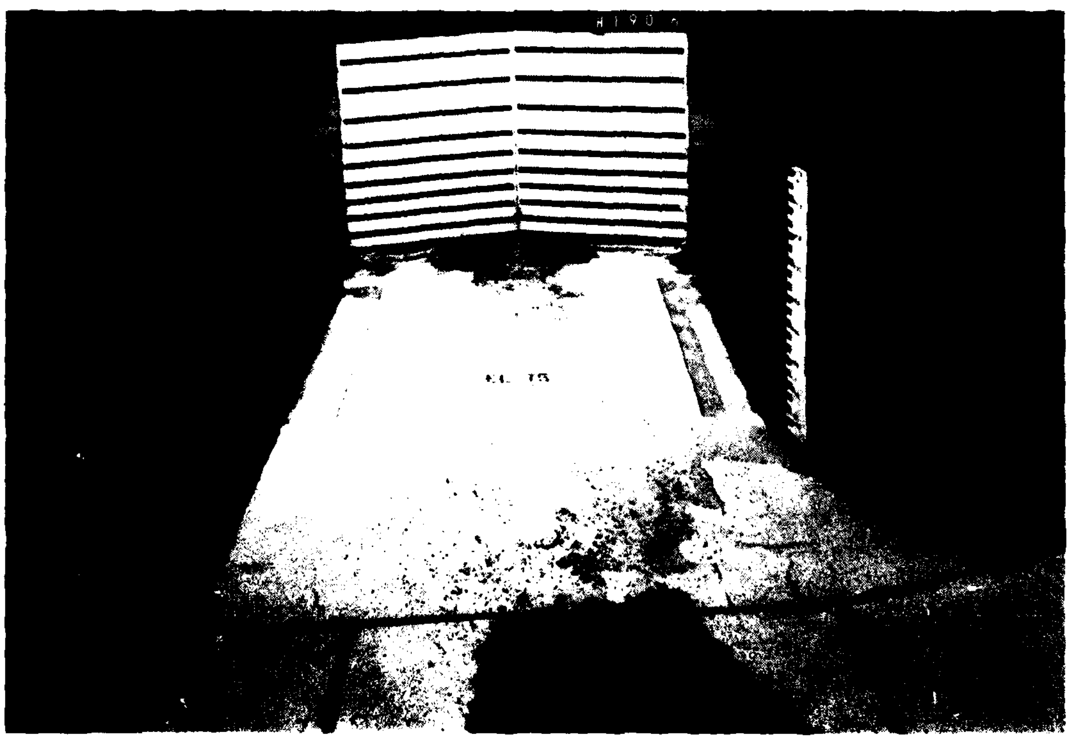
a. Coal placed near miter gates

b. Coal remaining after one emptying operation at maximum lift

Photo 11. Type 9 design outlet area (Continued)

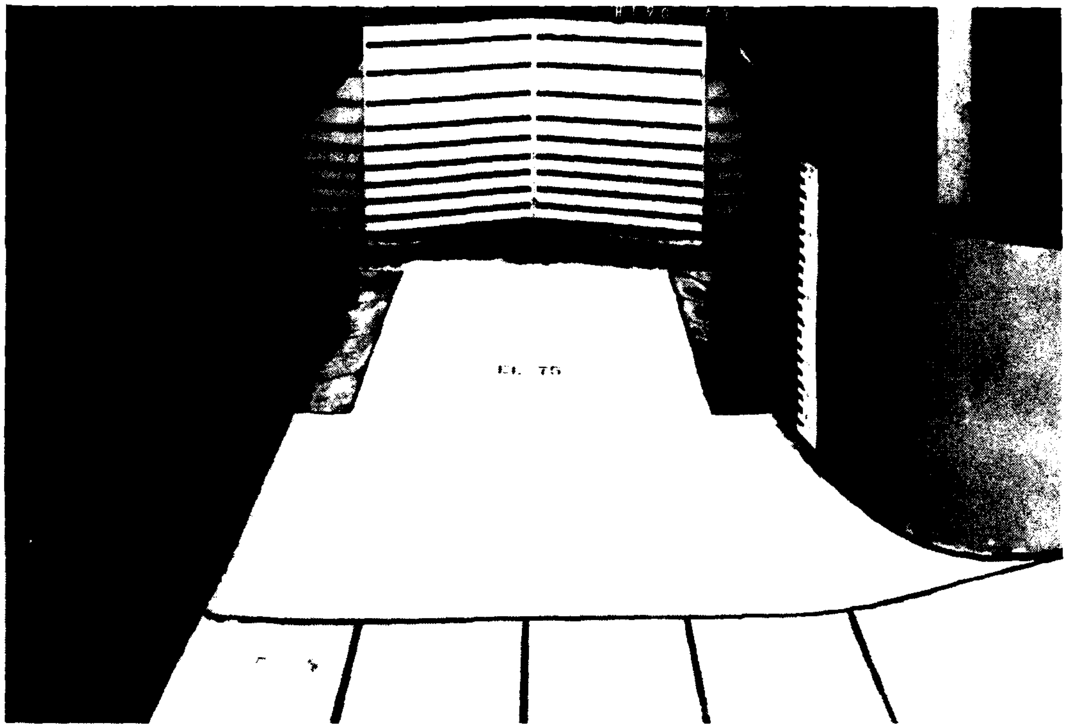


c. Coal remaining after one emptying operation at minimum lift

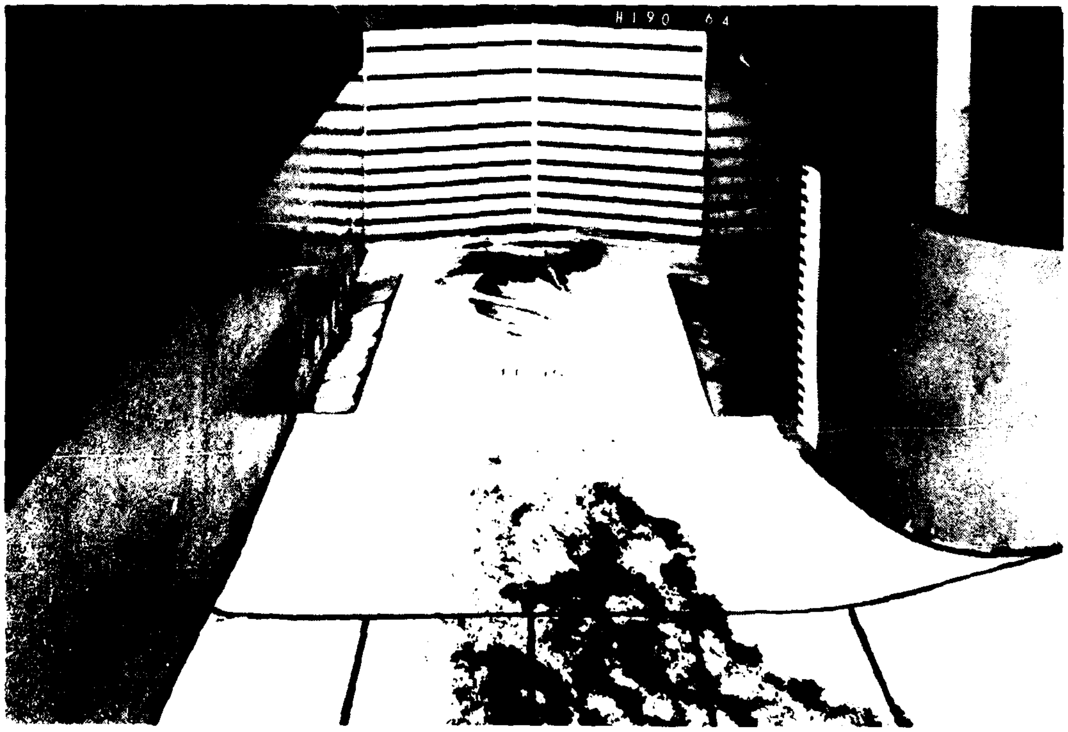


d. Coal remaining after 1 hr of steady flow at minimum lift

Photo 11. (Concluded)

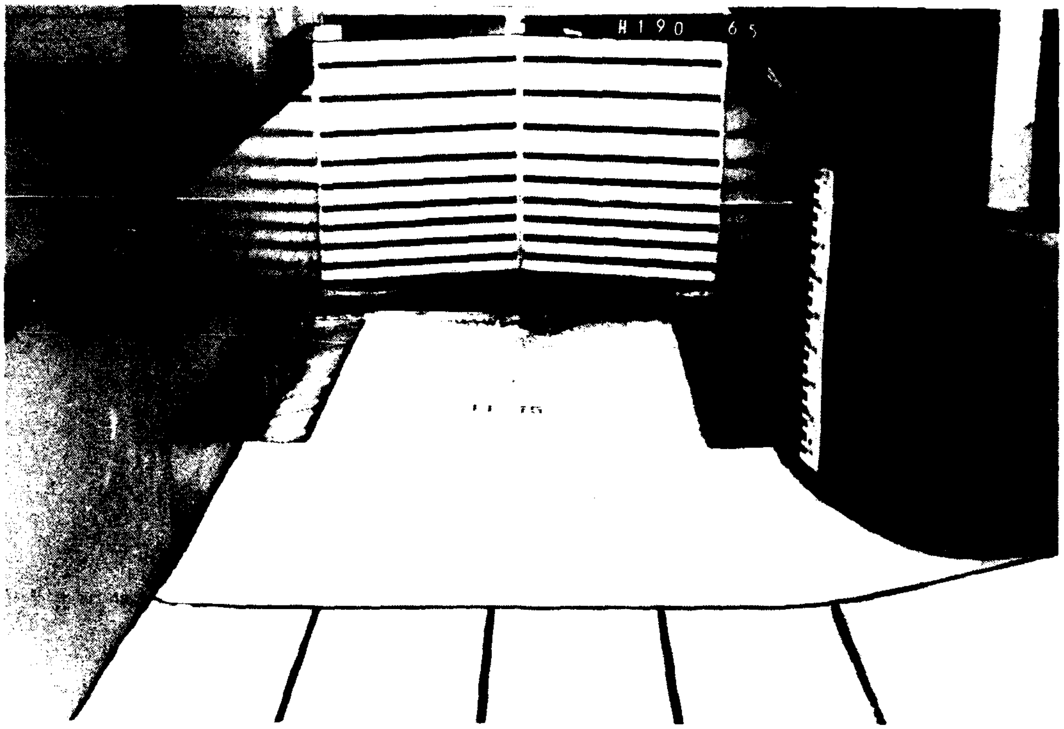


a. Coal placed near miter gates



b. Coal remaining after one emptying operation at maximum lift

Photo 12. Type 10 design outlet area (Continued)

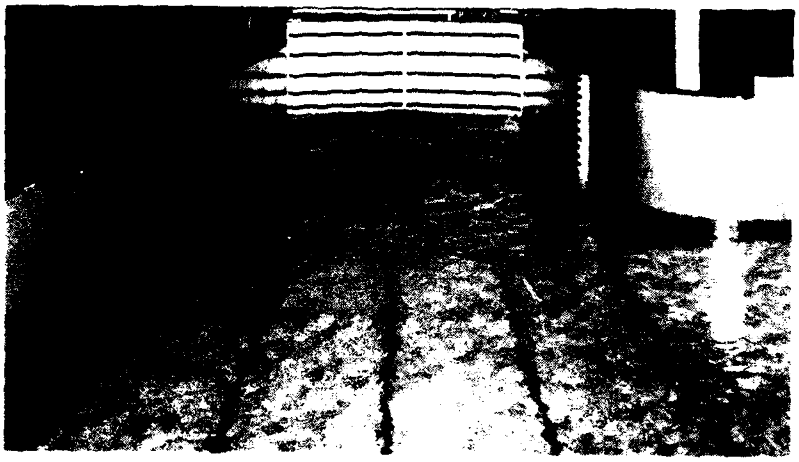


c. Coal remaining after one emptying operation at minimum lift

d. Coal remaining after 1 hr of steady flow at minimum lift

Photo 12. (Concluded)

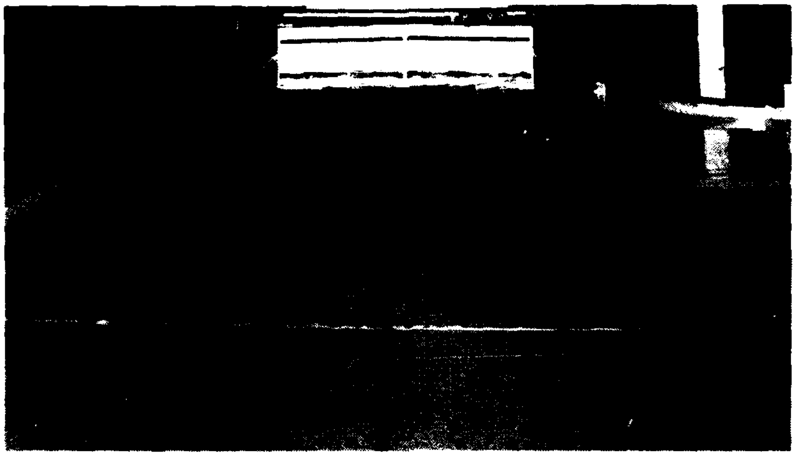
a. Normal valve



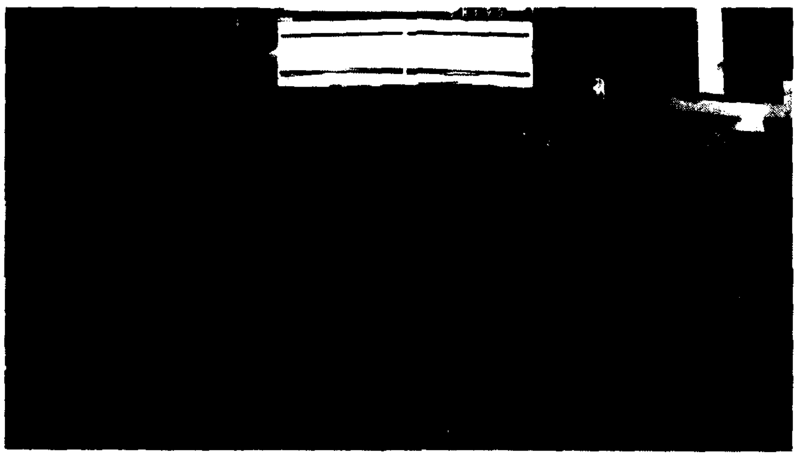
b. Single valve (left)

c. Single valve (right)

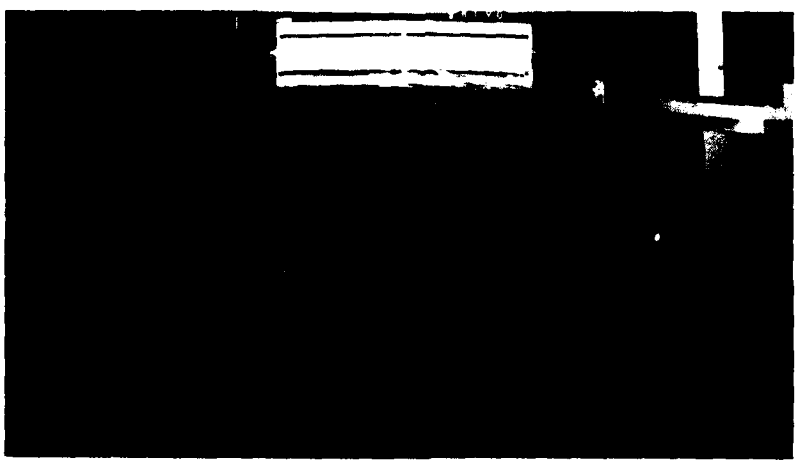
Photo 13. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 10 design outlet area; initial head 25 ft; initial lock chamber el 120; lower pool el 95



a. Normal valve

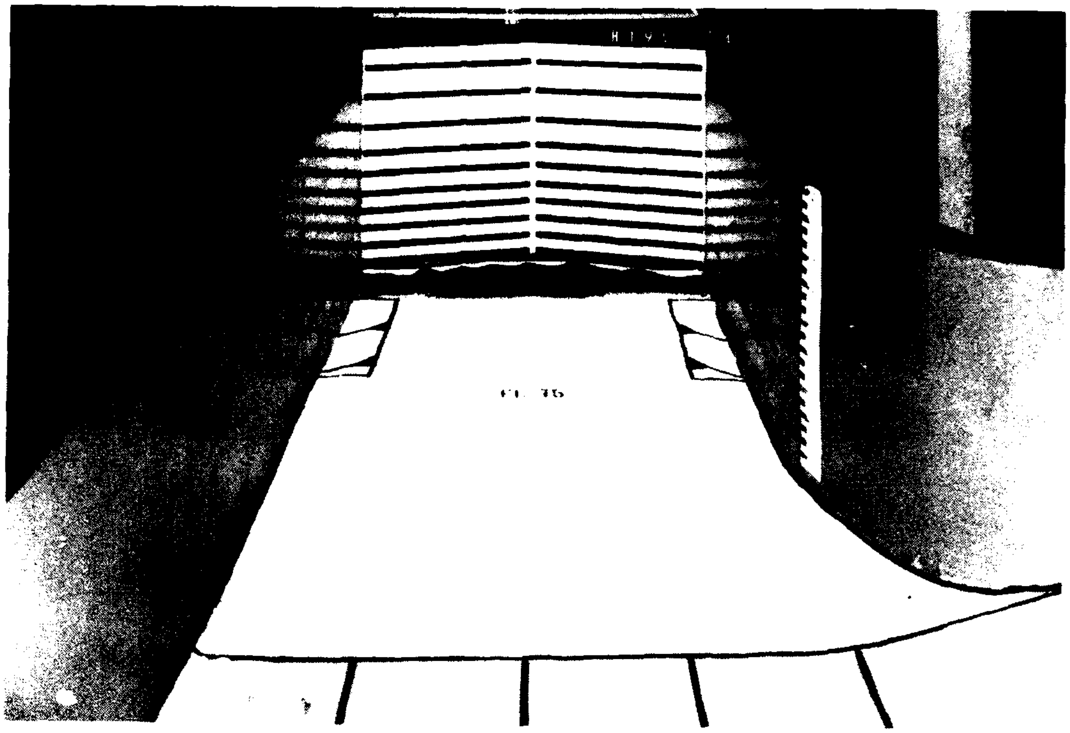


b. Single valve (left)

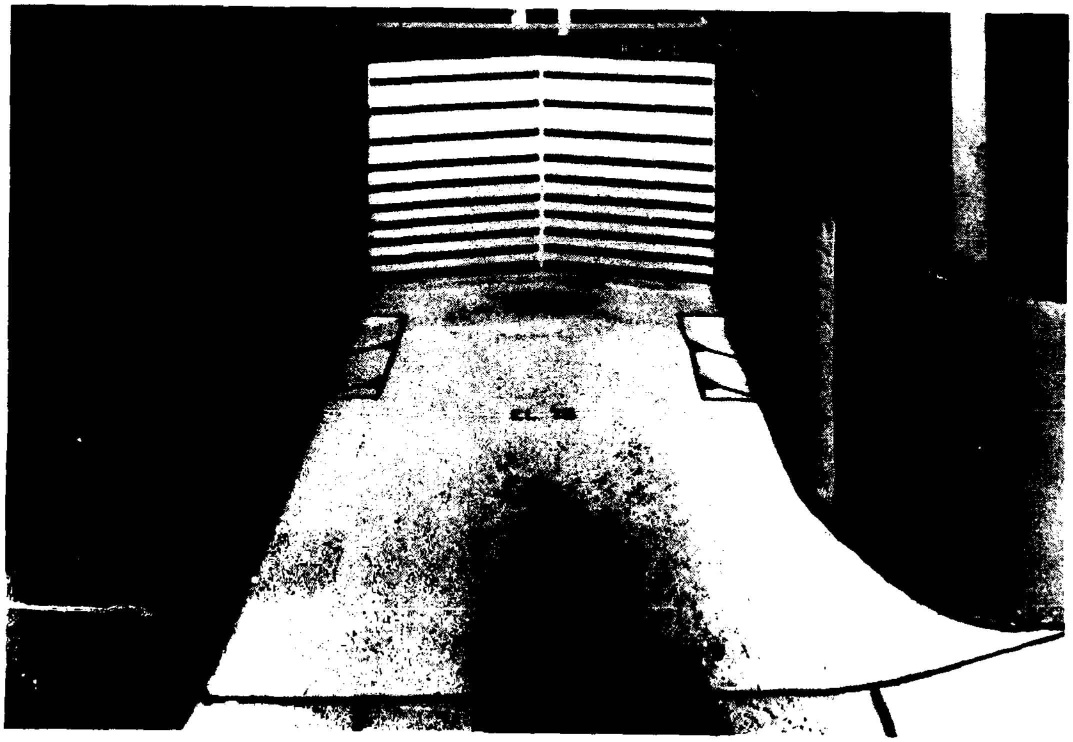


c. Single valve (right)

Photo 14. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 10 design outlet area; initial head 3.5 ft; initial lock chamber el 121.7; lower pool el 118.2

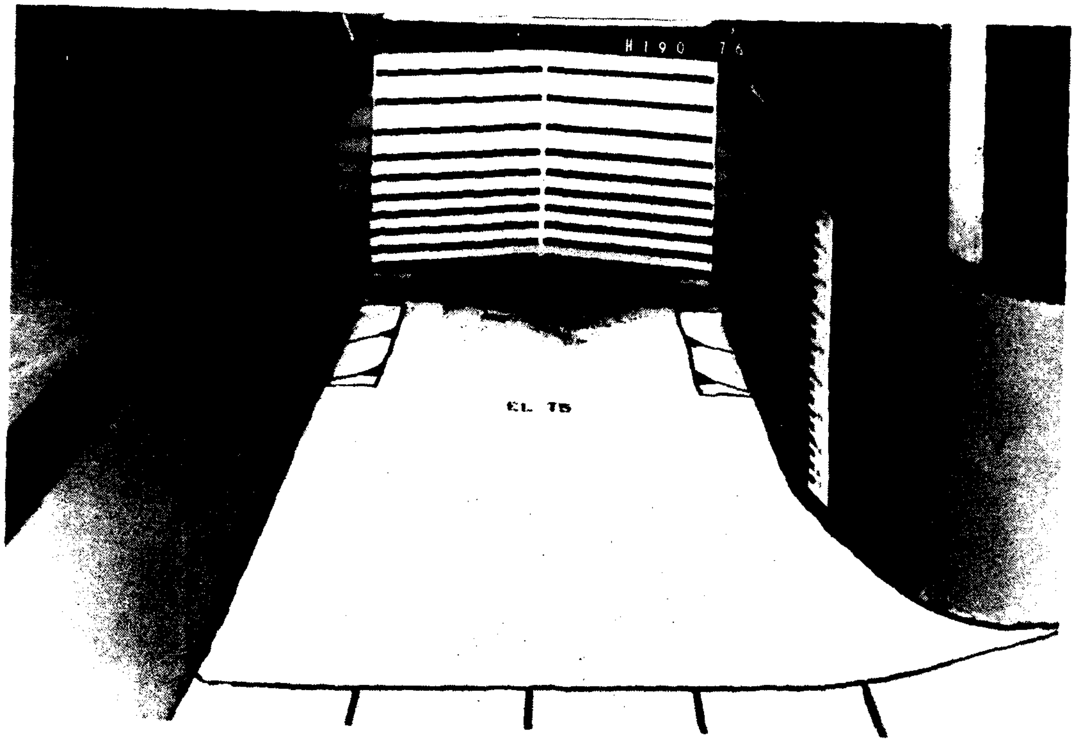


a. Coal placed near miter gates

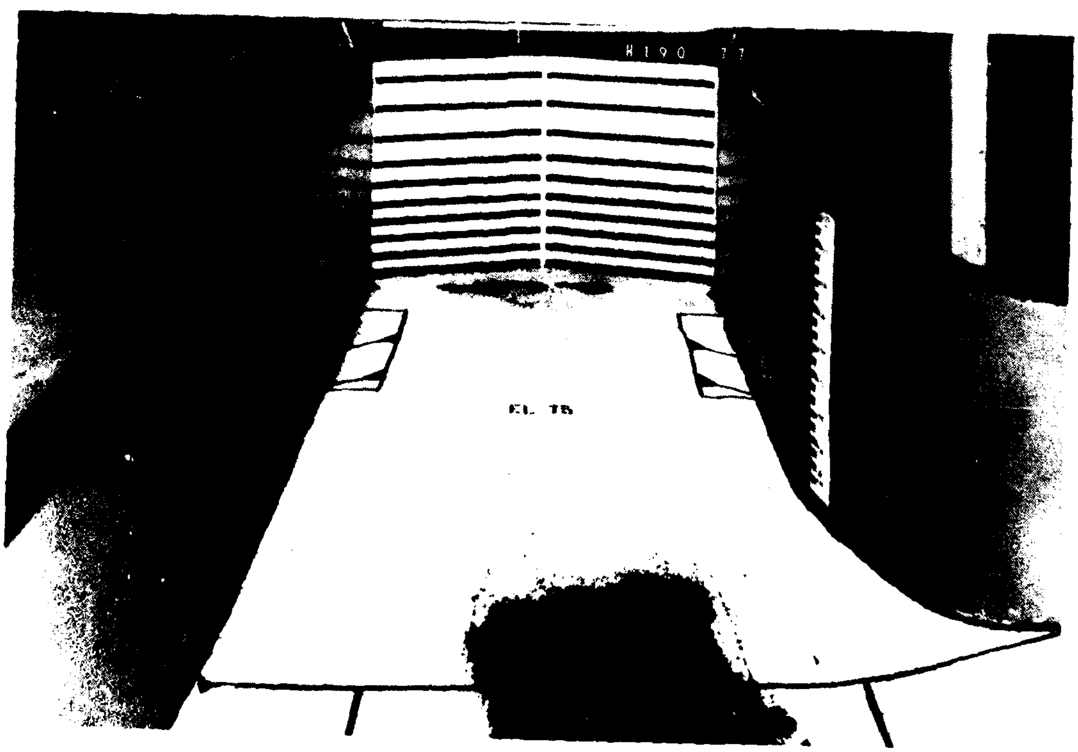


b. Coal remaining after one emptying operation at maximum lift

Photo 15. Type 11 design outlet area (Continued)

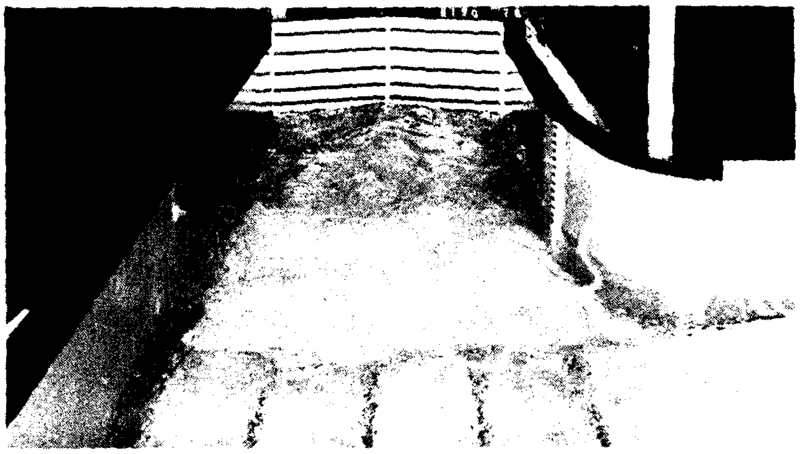



c. Coal remaining after one emptying operation at minimum lift

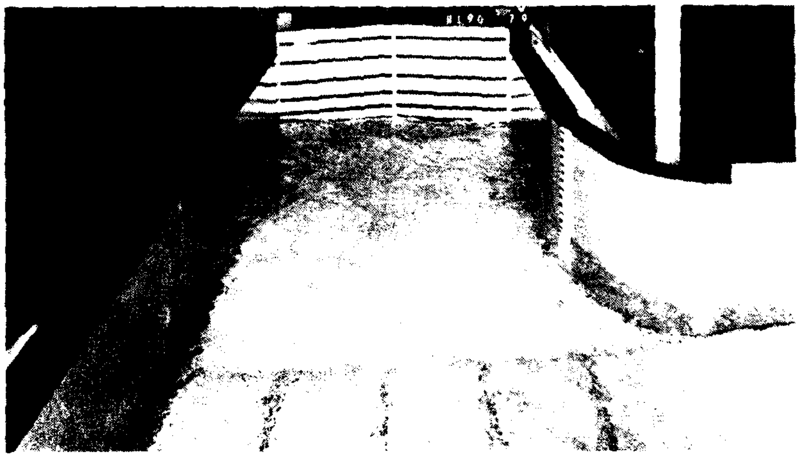



d. Coal remaining after 1 hr of steady flow at minimum lift

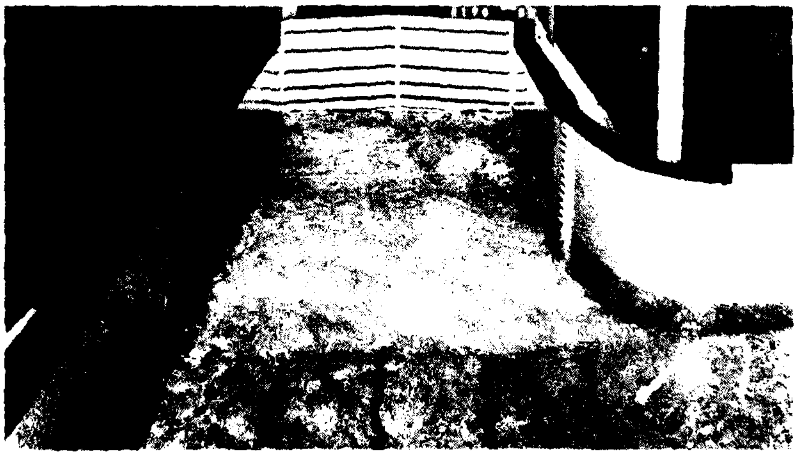
Photo 15. (Concluded)



a. Normal valve

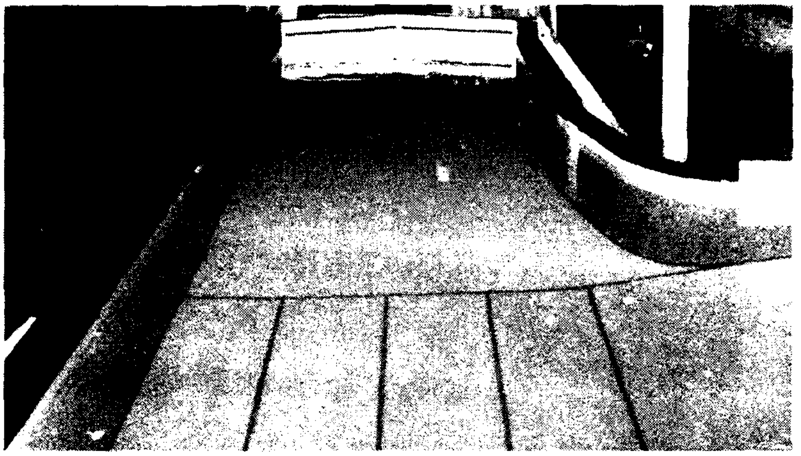


b. Single valve (left)



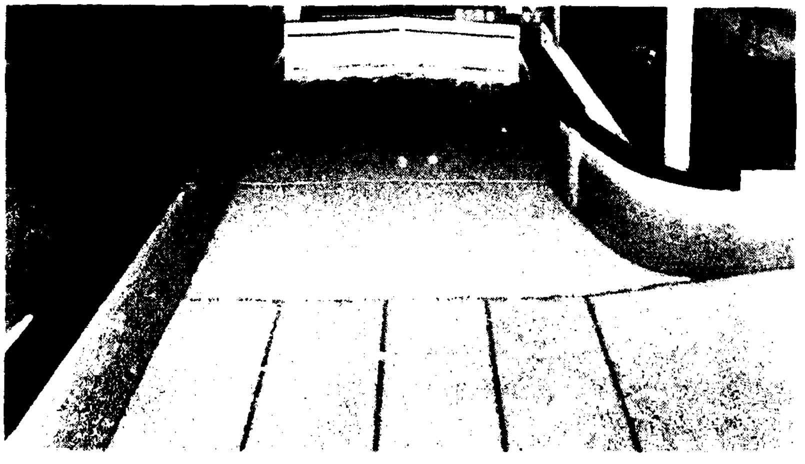
c. Single valve (right)

Photo 16. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 11 design outlet area; initial head 25 ft; initial lock chamber el 120; lower pool el 95



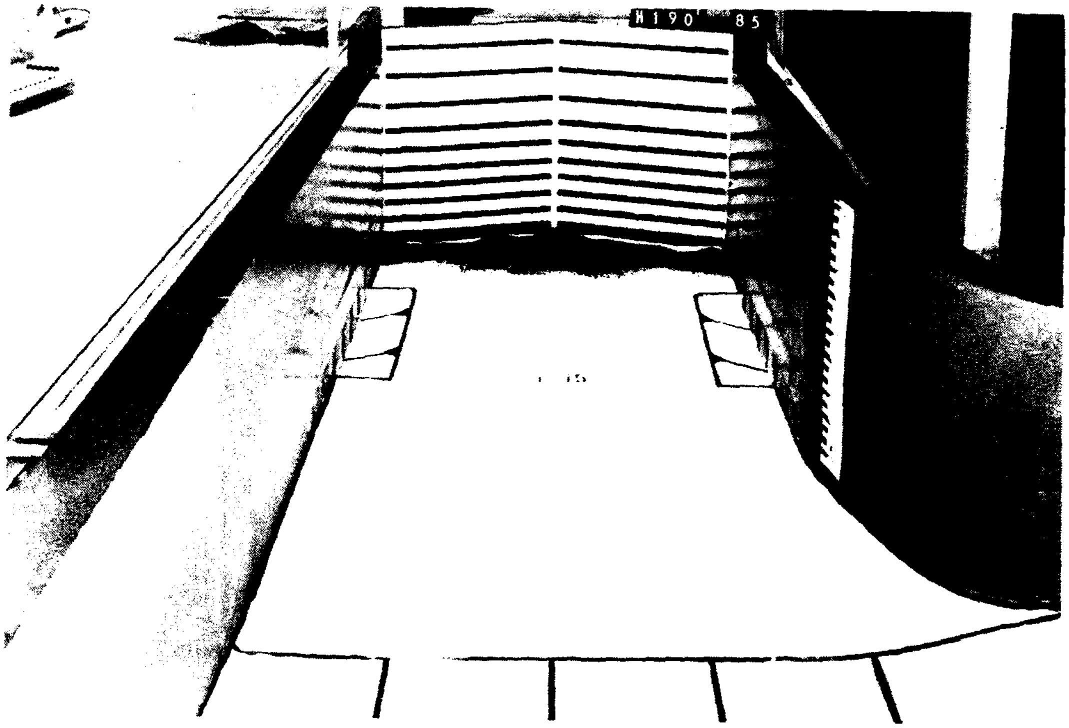
a. Normal valve

b. Single valve (left)

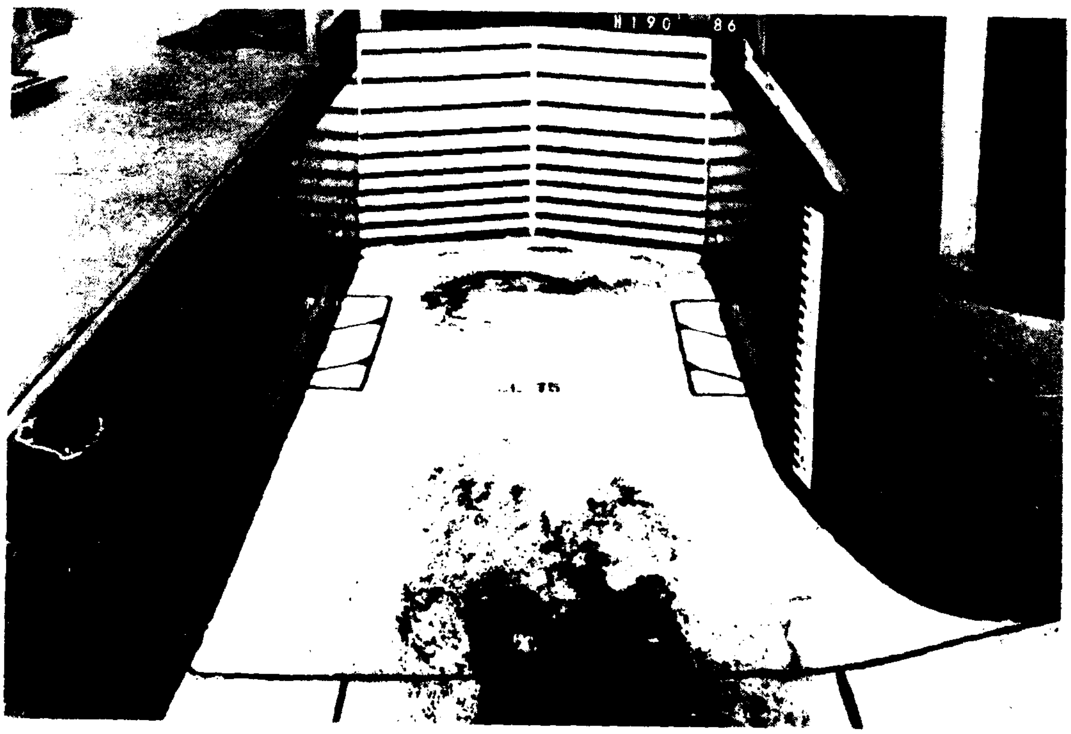


c. Single valve (right)

Photo 17. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 11 design outlet area; initial head 3.5 ft; initial lock chamber el 121.7; lower pool el 118.2

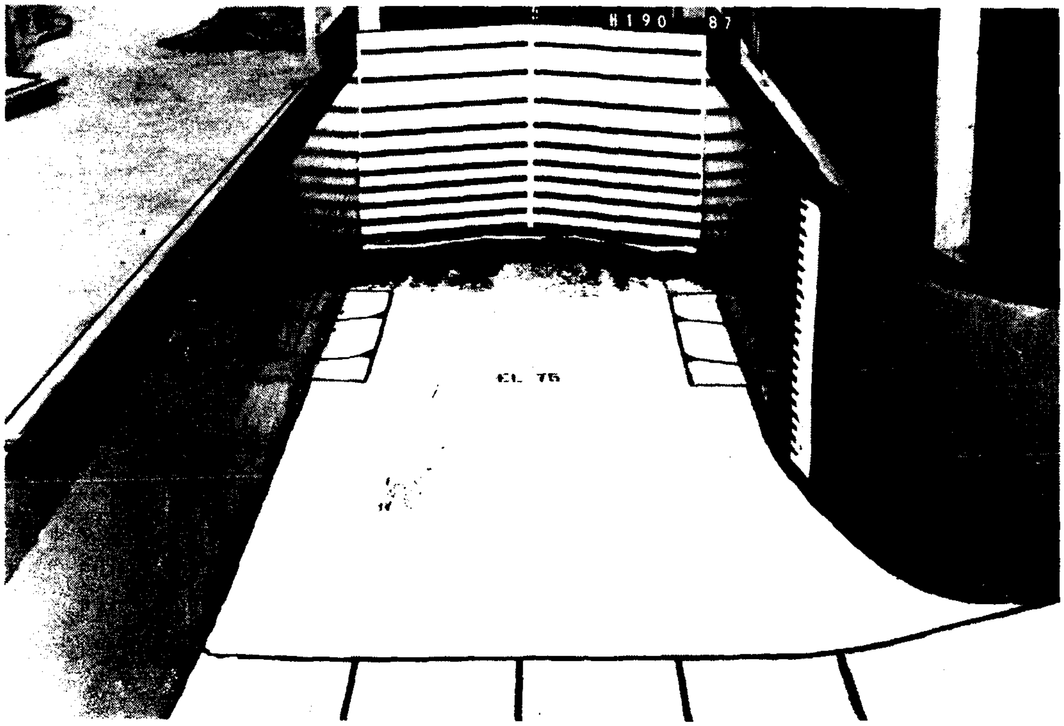



a. Coal placed near miter gates

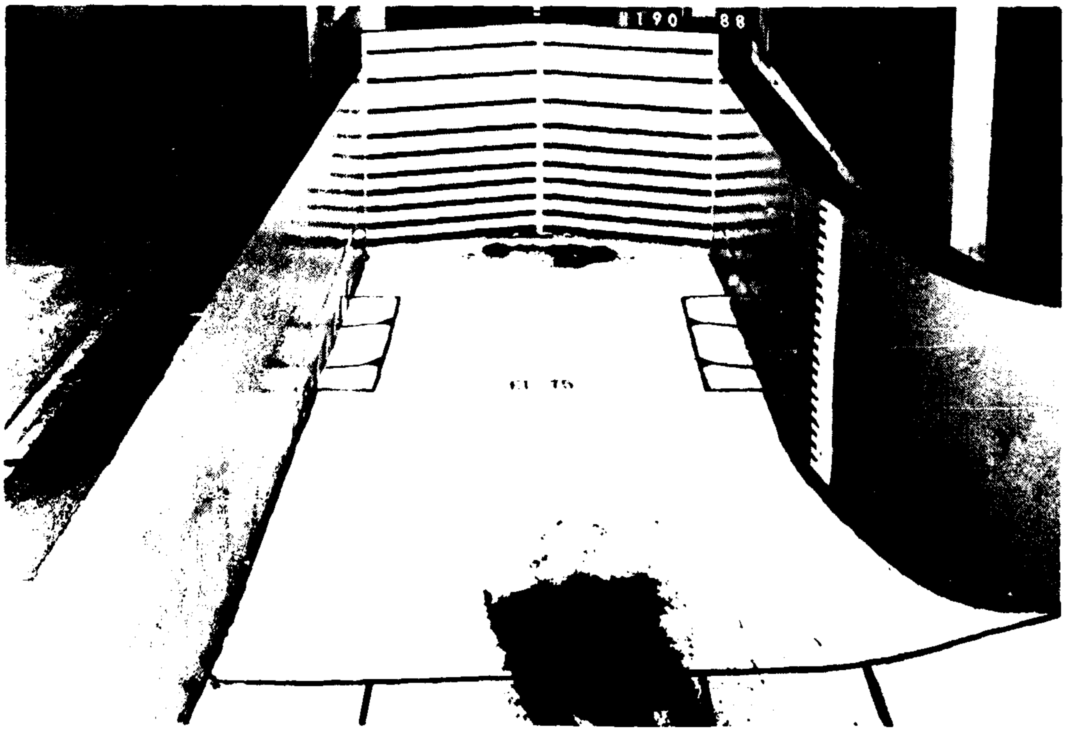



b. Coal remaining after one emptying operation at maximum lift

Photo 18. Type 12 design outlet area (Continued)

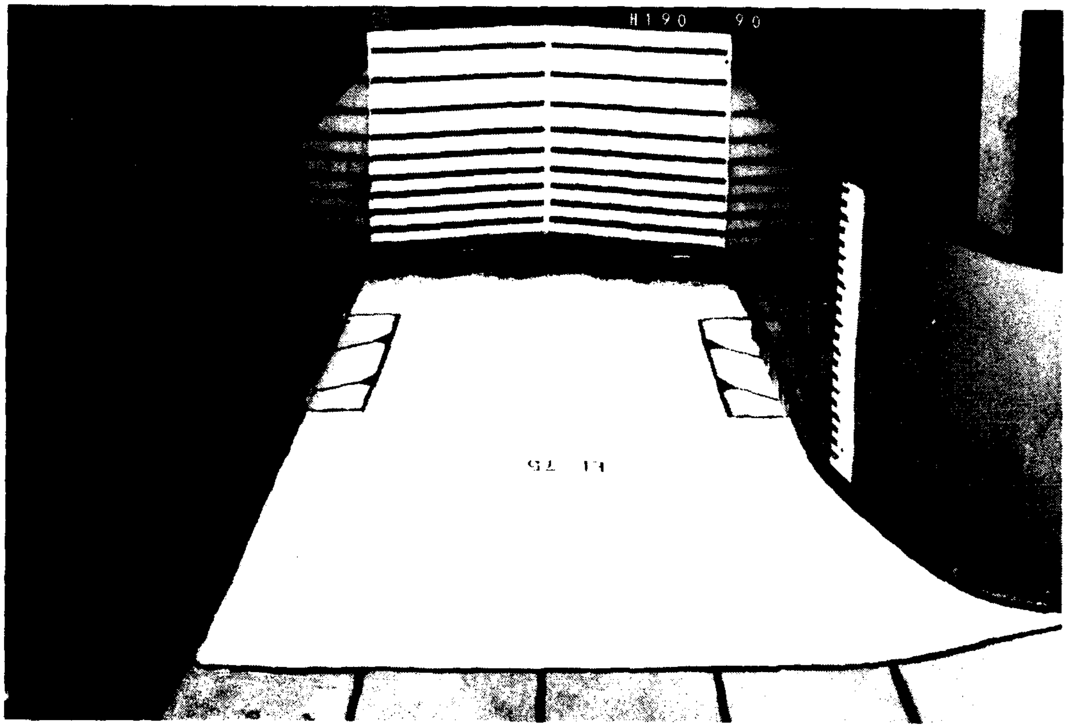



c. Coal remaining after one emptying operation at minimum lift

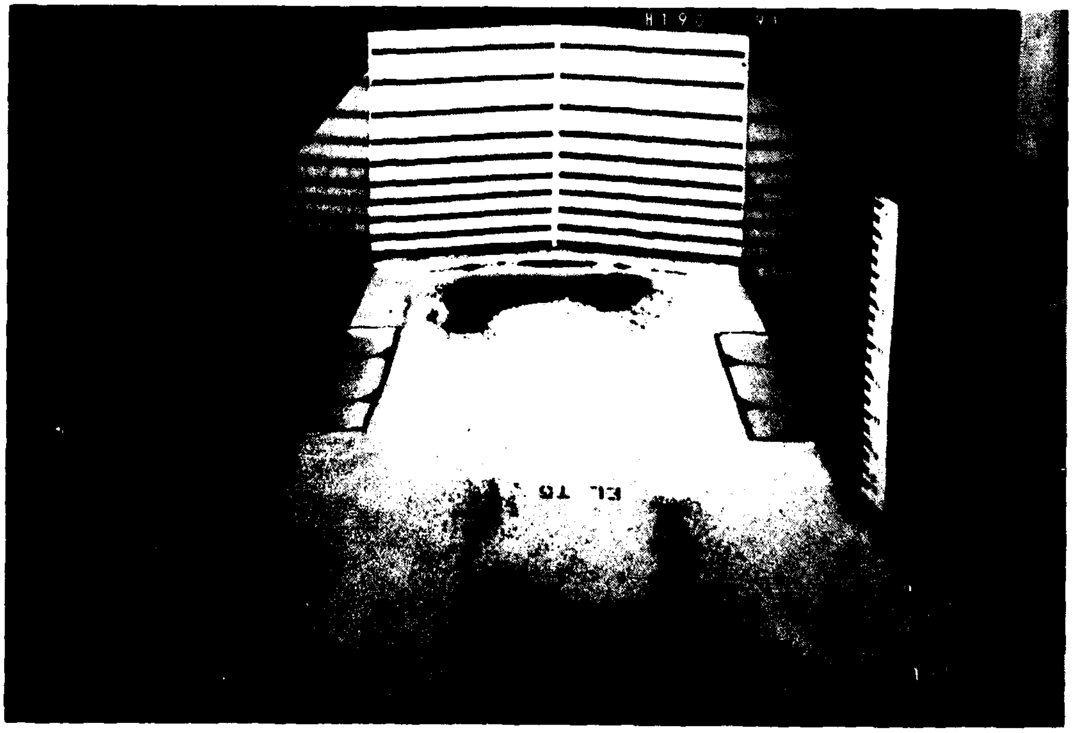



d. Coal remaining after 1 hr of steady flow at minimum lift

Photo 18. (Concluded)

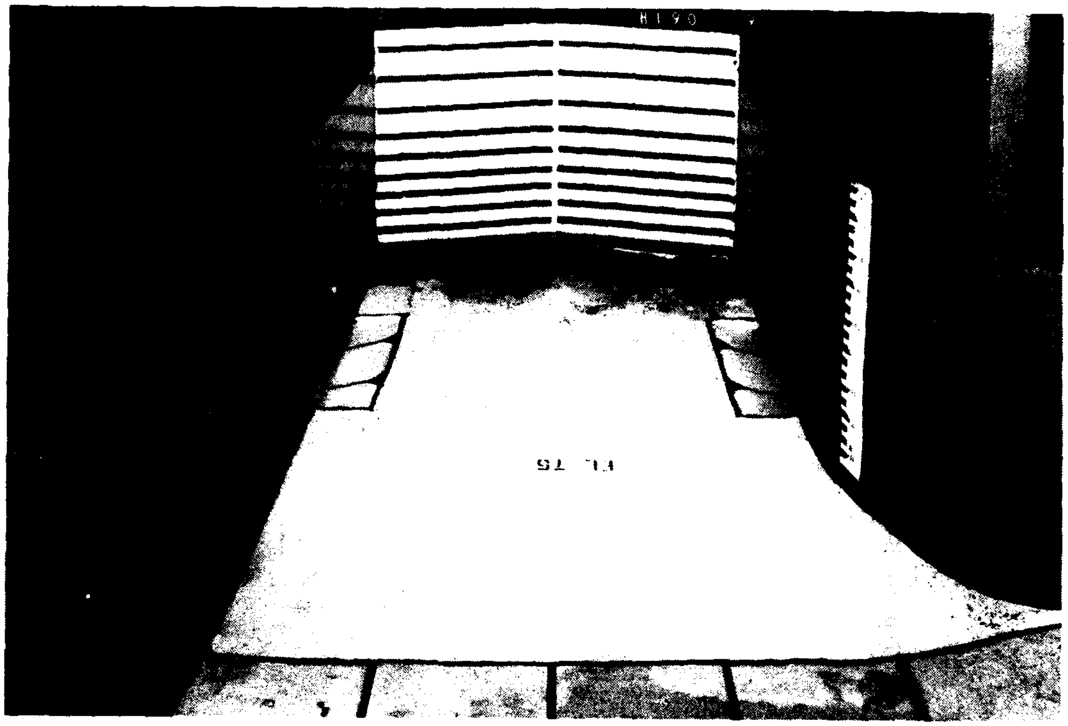


a. Coal placed near miter gates

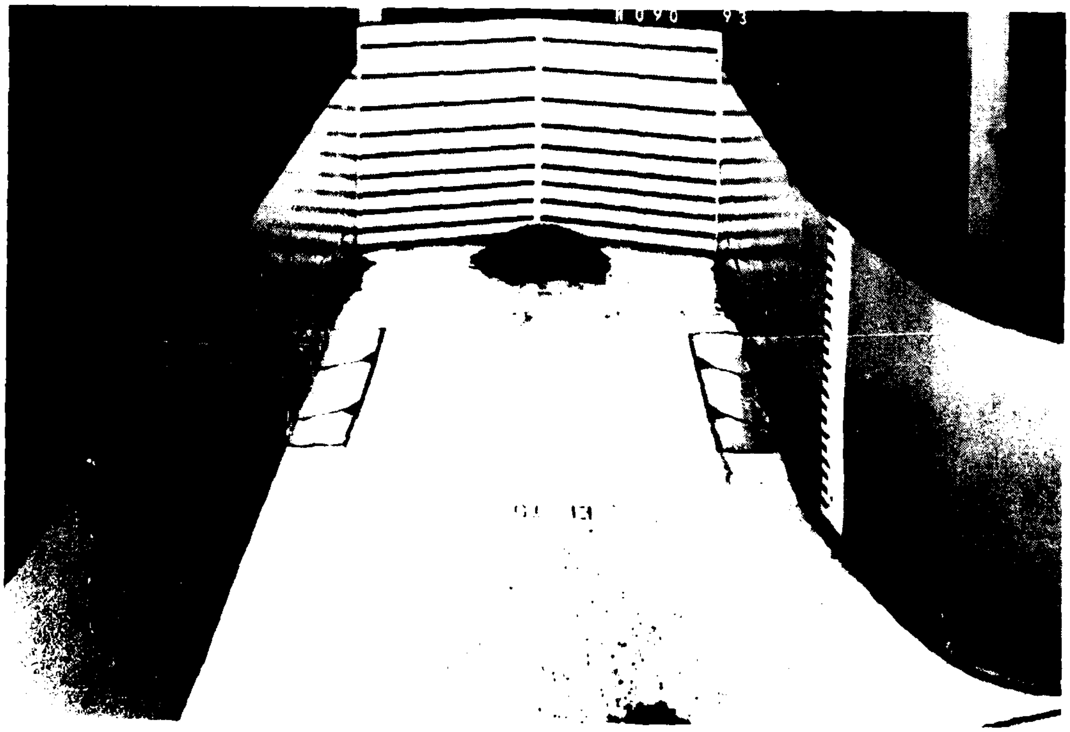


b. Coal remaining after one emptying operation at maximum lift

Photo 19. Type 13 design outlet area (Continued)

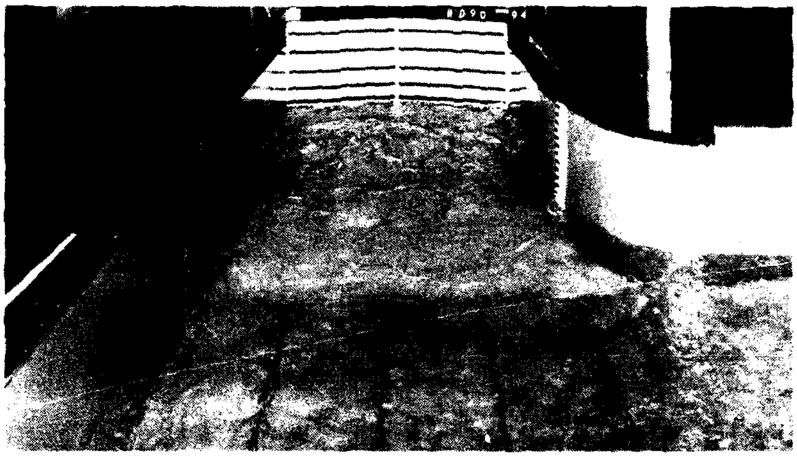


c. Coal remaining after one emptying operation at minimum lift

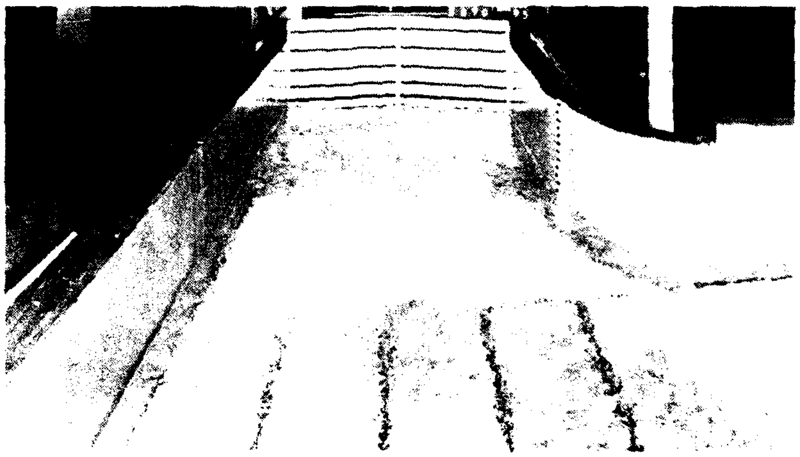


d. Coal remaining after 1 hr of steady flow at minimum lift

Photo 19. (Concluded)



a. Normal valve

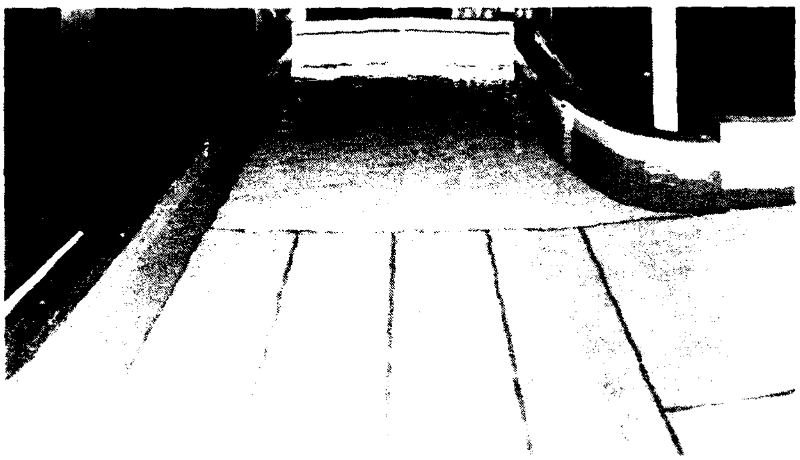


b. Single valve (left)

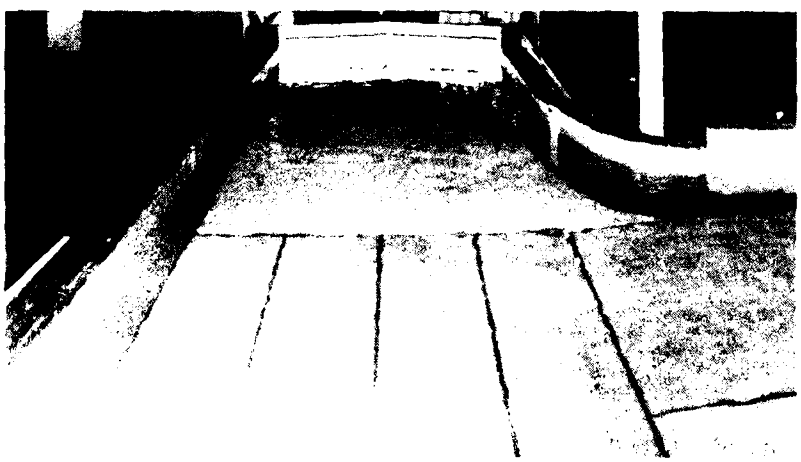
c. Single valve (right)

Photo 20. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 13 design outlet area; initial head 25 ft; initial lock chamber el 120; lower pool el 95

a. Normal valve



b. Single valve (left)



c. Single valve (right)

Photo 21. Maximum discharge and flow conditions for emptying operations with 4-min valve; type 13 design outlet area; initial head 3.5 ft; initial lock chamber el 121.7; lower pool el 118.2

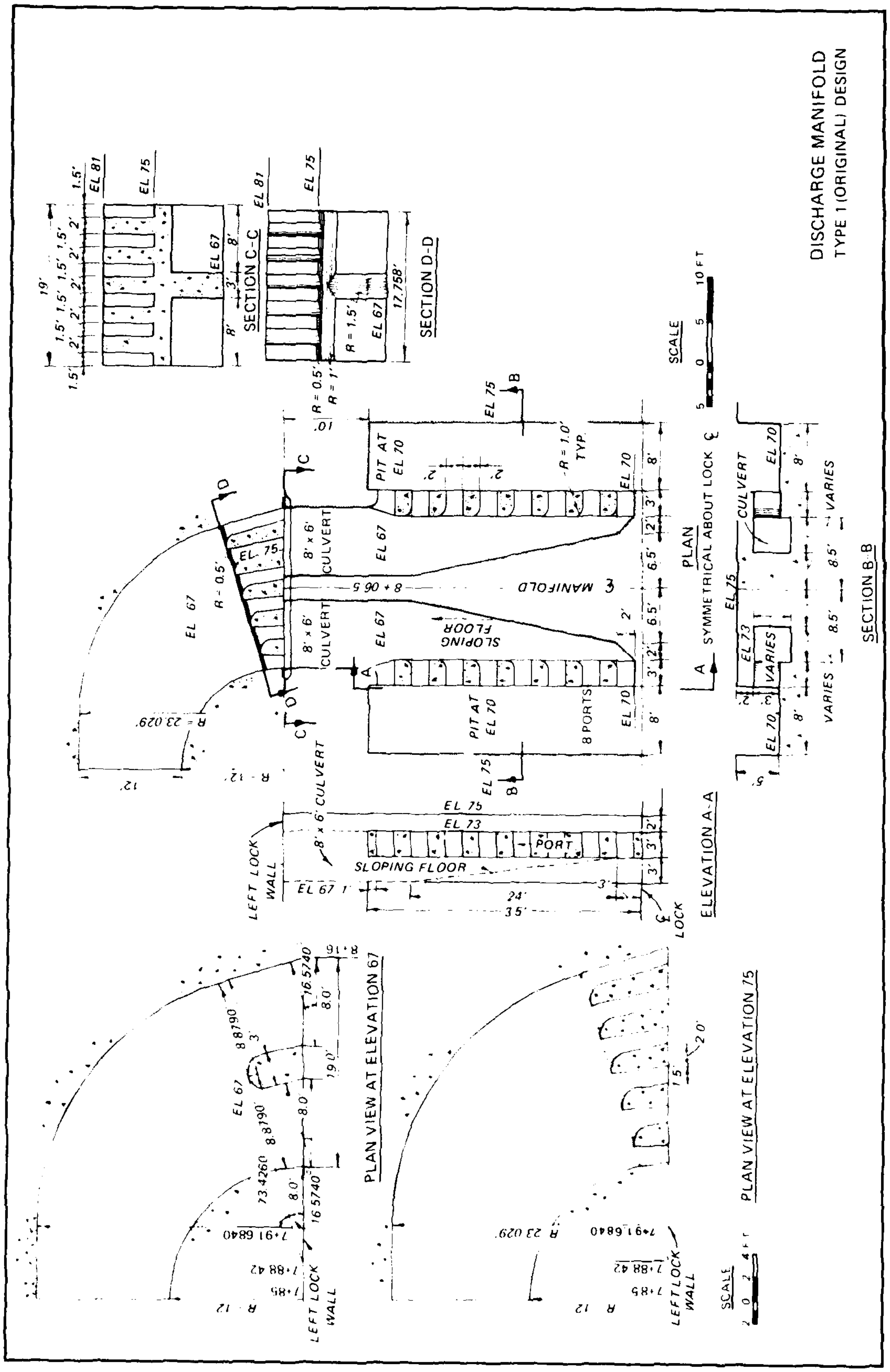

DISCHARGE MANIFOLD
TYPE 1 (ORIGINAL) DESIGN
SECTION C-C
SECTION D-D
PLAN
SYMMETRICAL ABOUT LOCK ℄
SECTION B-B
ELEVATION A-A
PLAN VIEW AT ELEVATION 67
PLAN VIEW AT ELEVATION 75
SCALE
8' x 6' CULVERT
SLOPING FLOOR
℄ MANIFOLD
PIT AT EL 70
8 PORTS
PORT
LEFT LOCK WALL
℄ LOCK
R = 23.029'
R = 1.0' TYP.
17.758'
8 + 06.5
7+85
7+88.42
7+91.6840
8+16
VARIES
CULVERT

PLATE 1

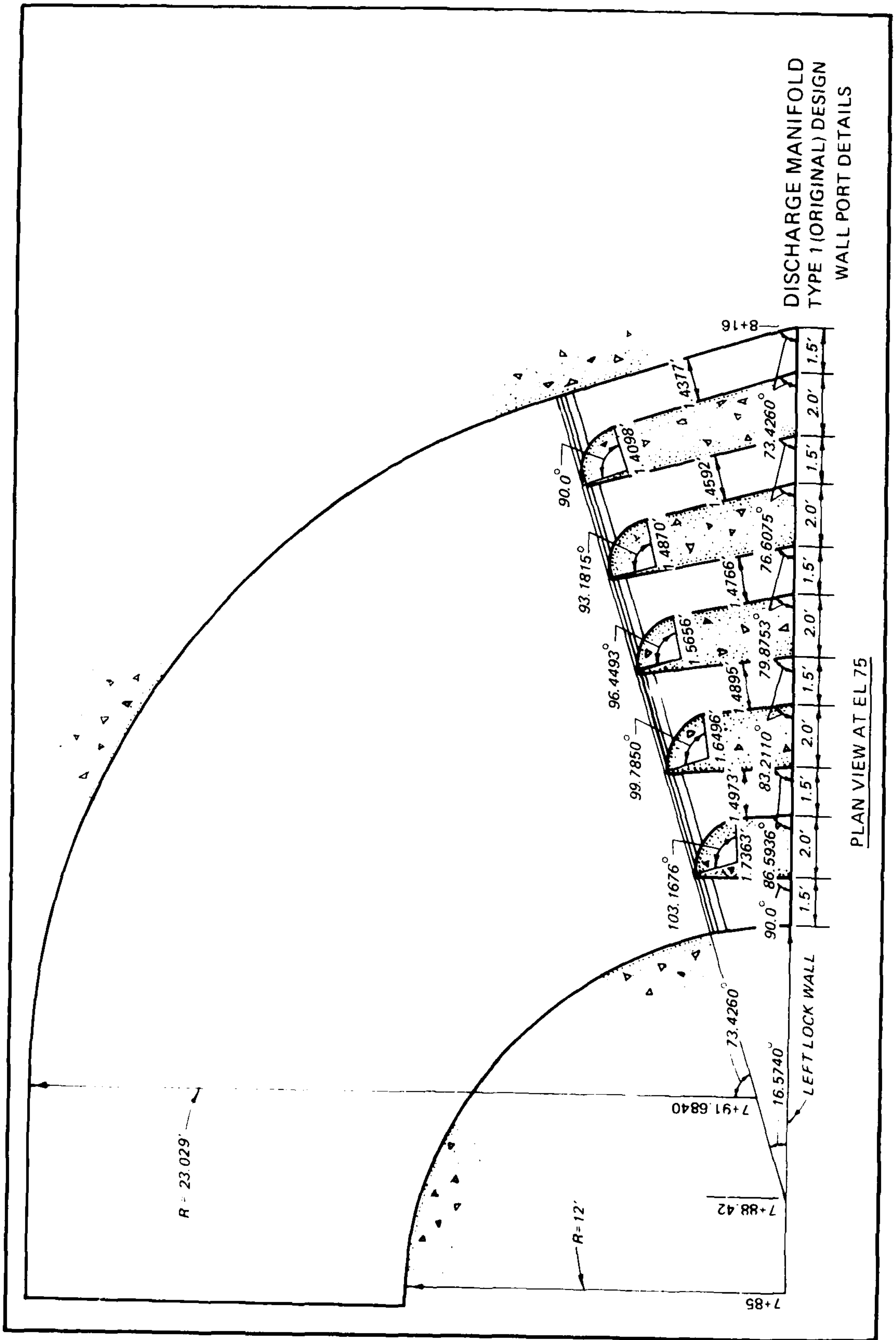
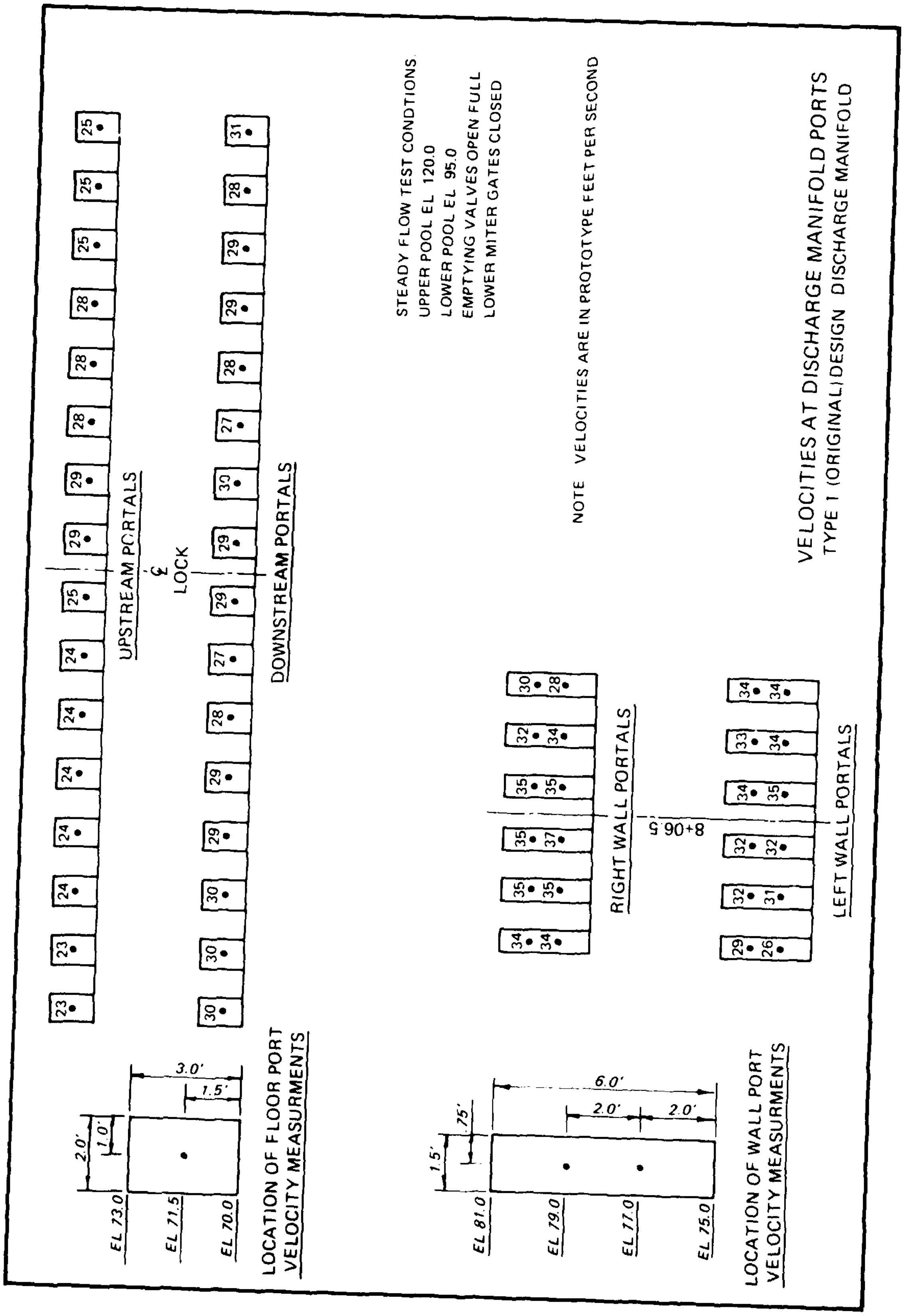
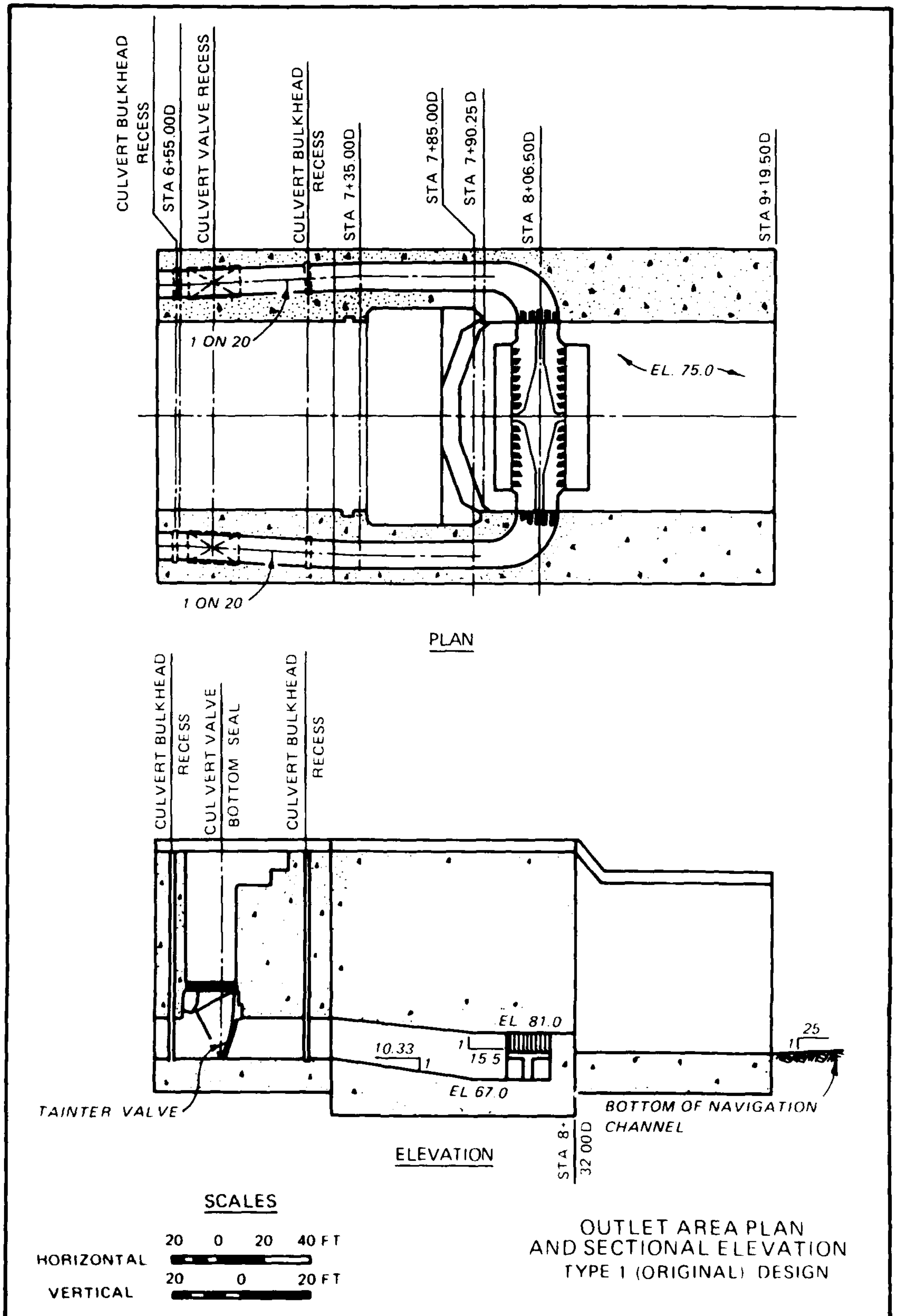

DISCHARGE MANIFOLD
TYPE 1 (ORIGINAL) DESIGN
WALL PORT DETAILS
PLAN VIEW AT EL 75
LEFT LOCK WALL
R = 23.029'
R = 12'
7+85
7+88.42
7+91.6840
8+16
16.5740°
73.4260°
90.0°
103.1676°
86.5936°
1.7363'
1.4973'
99.7850°
83.2110°
1.6496'
1.4895'
96.4493°
79.8753°
1.5656'
1.4766'
93.1815°
76.6075°
1.4870'
1.4592'
90.0°
73.4260°
1.4098'
1.4377'
1.5'
2.0'
1.5'
2.0'
1.5'
2.0'
1.5'
2.0'
1.5'
2.0'
1.5'

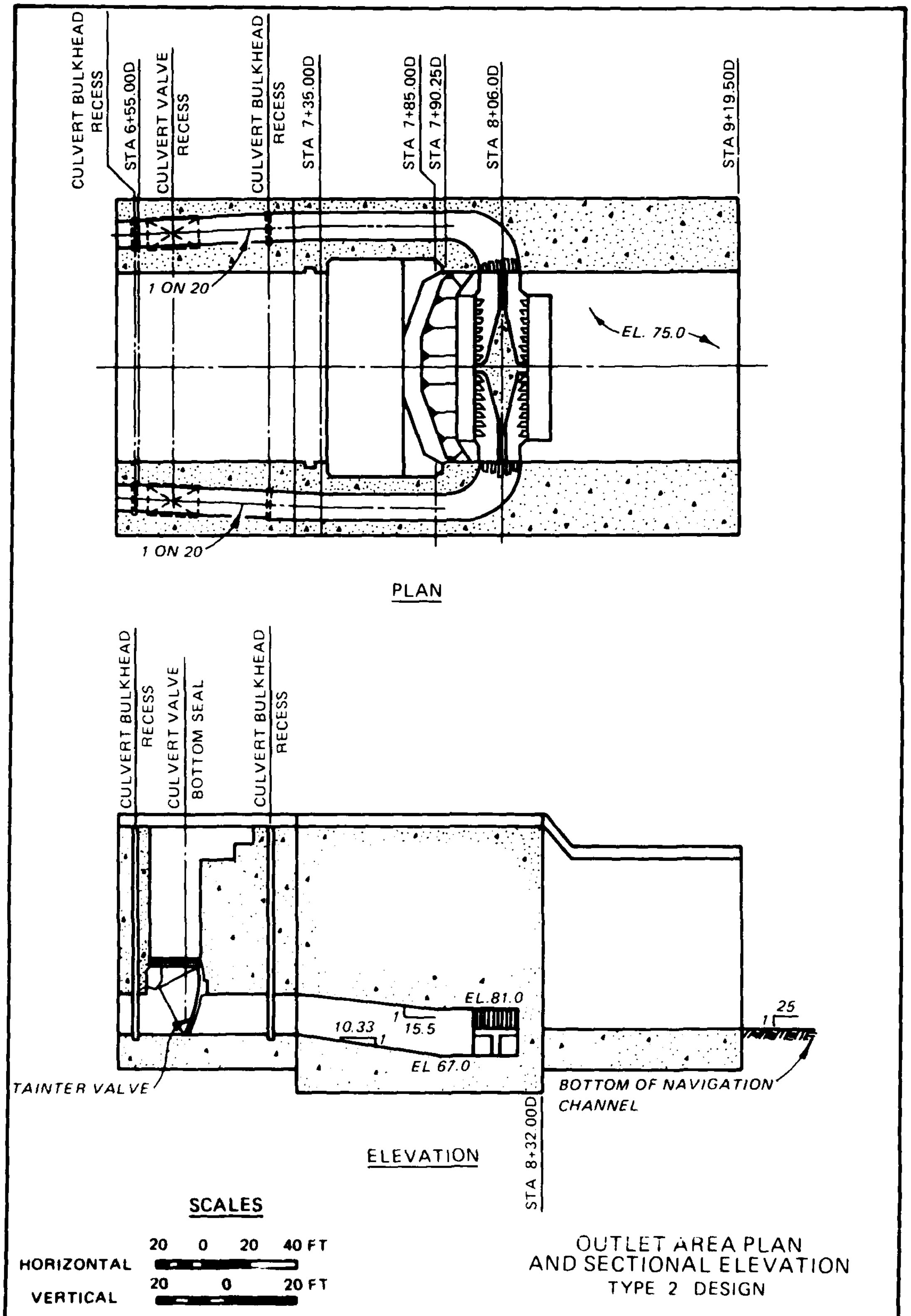
PLATE 2



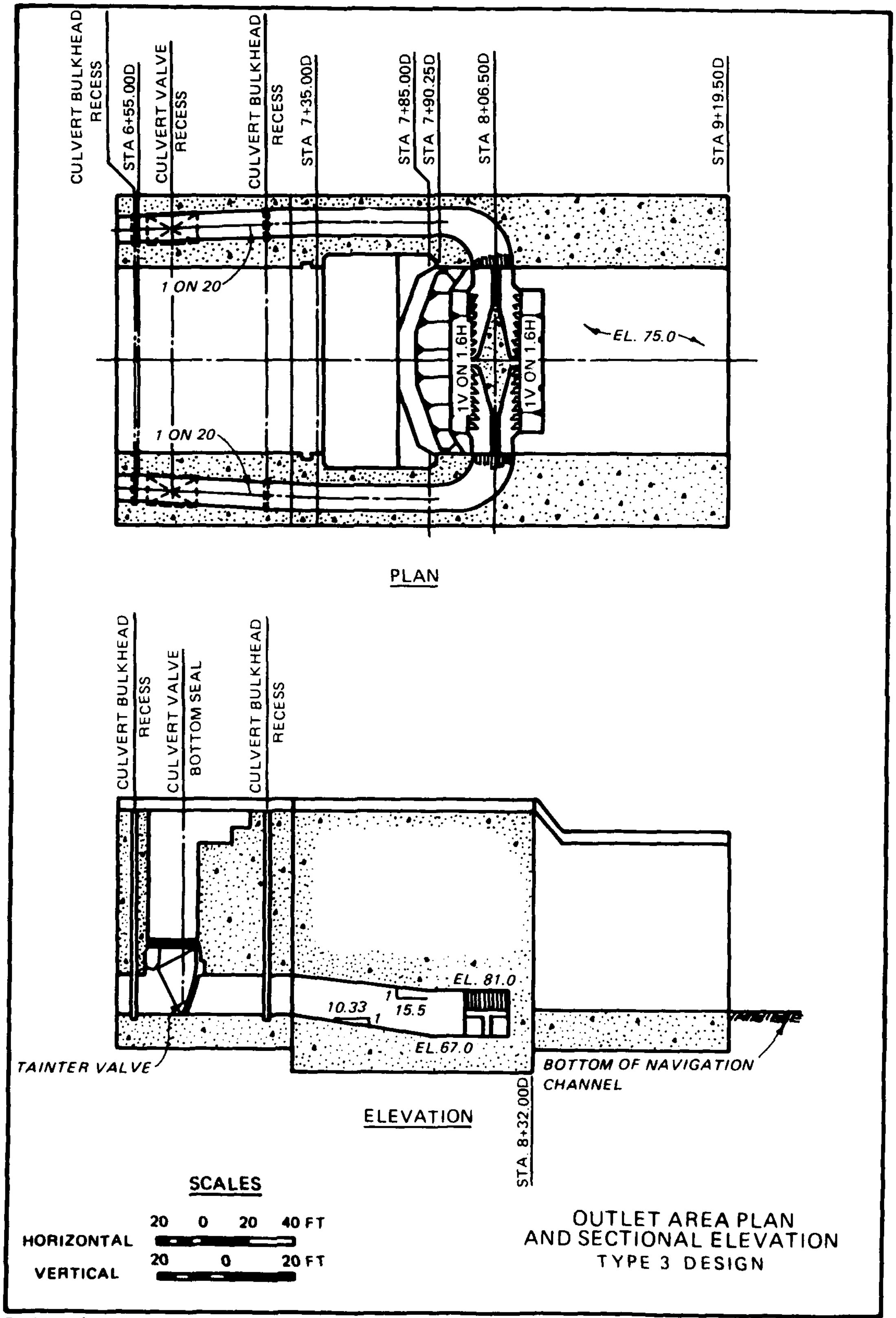
VELOCITIES AT DISCHARGE MANIFOLD PORTS
TYPE 1 (ORIGINAL) DESIGN DISCHARGE MANIFOLD



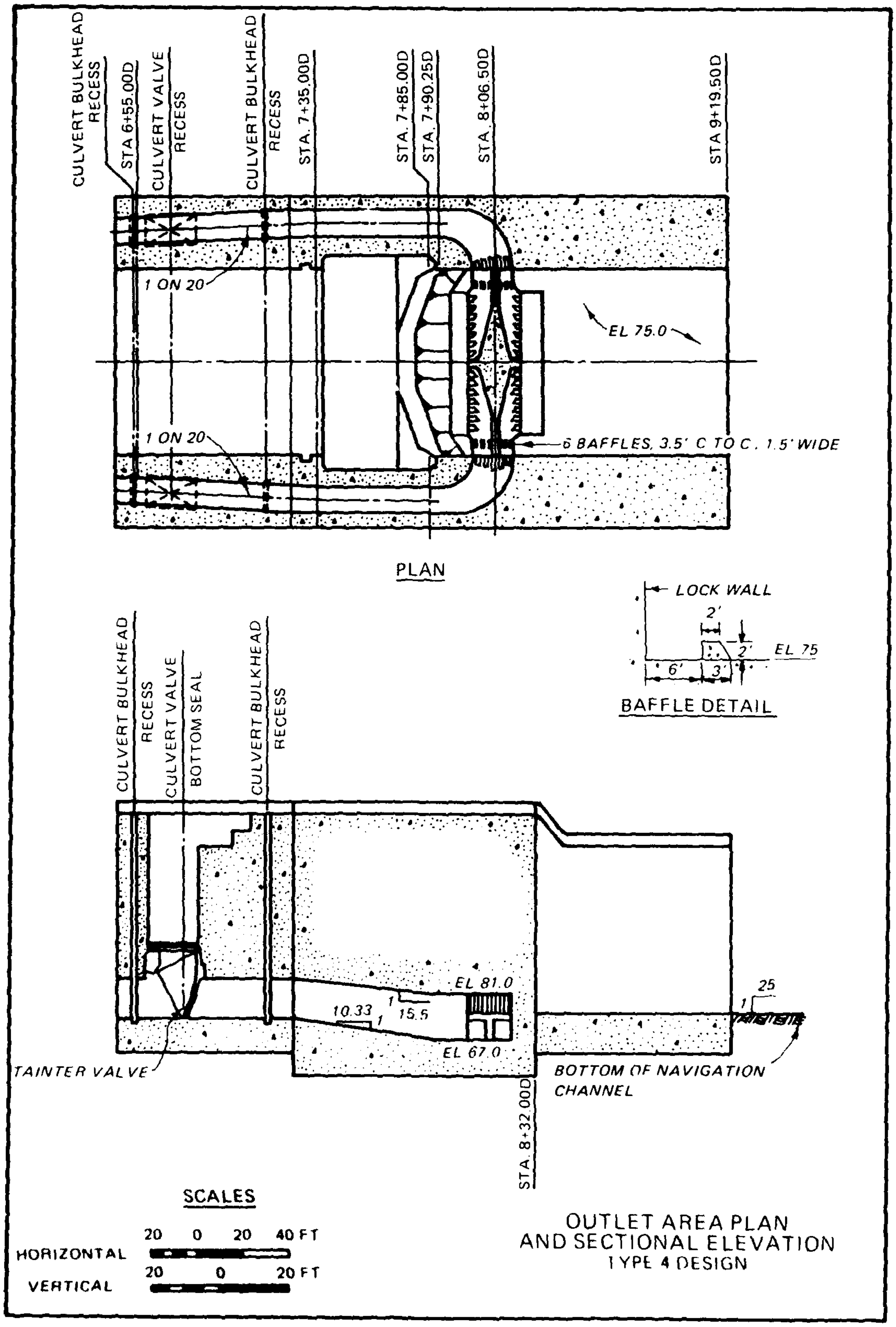

OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 1 (ORIGINAL) DESIGN




OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 2 DESIGN




OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 3 DESIGN


CULVERT BULKHEAD RECESS
STA 6+55.00D
CULVERT VALVE RECESS
CULVERT BULKHEAD RECESS
STA. 7+35.00D
STA. 7+85.00D
STA. 7+90.25D
STA. 8+06.50D
STA 9+19.50D
1 ON 20
EL 75.0
1 ON 20
6 BAFFLES, 3.5' C TO C, 1.5' WIDE
PLAN
LOCK WALL
2'
2'
EL 75
6'
3'
BAFFLE DETAIL
CULVERT BULKHEAD RECESS
CULVERT VALVE
BOTTOM SEAL
CULVERT BULKHEAD RECESS
EL 81.0
25
1
10.33
1
1
15.5
EL 67.0
TAINTER VALVE
BOTTOM OF NAVIGATION CHANNEL
STA. 8+32.00D
SCALES
HORIZONTAL
20 0 20 40 FT
VERTICAL
20 0 20 FT
OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 4 DESIGN

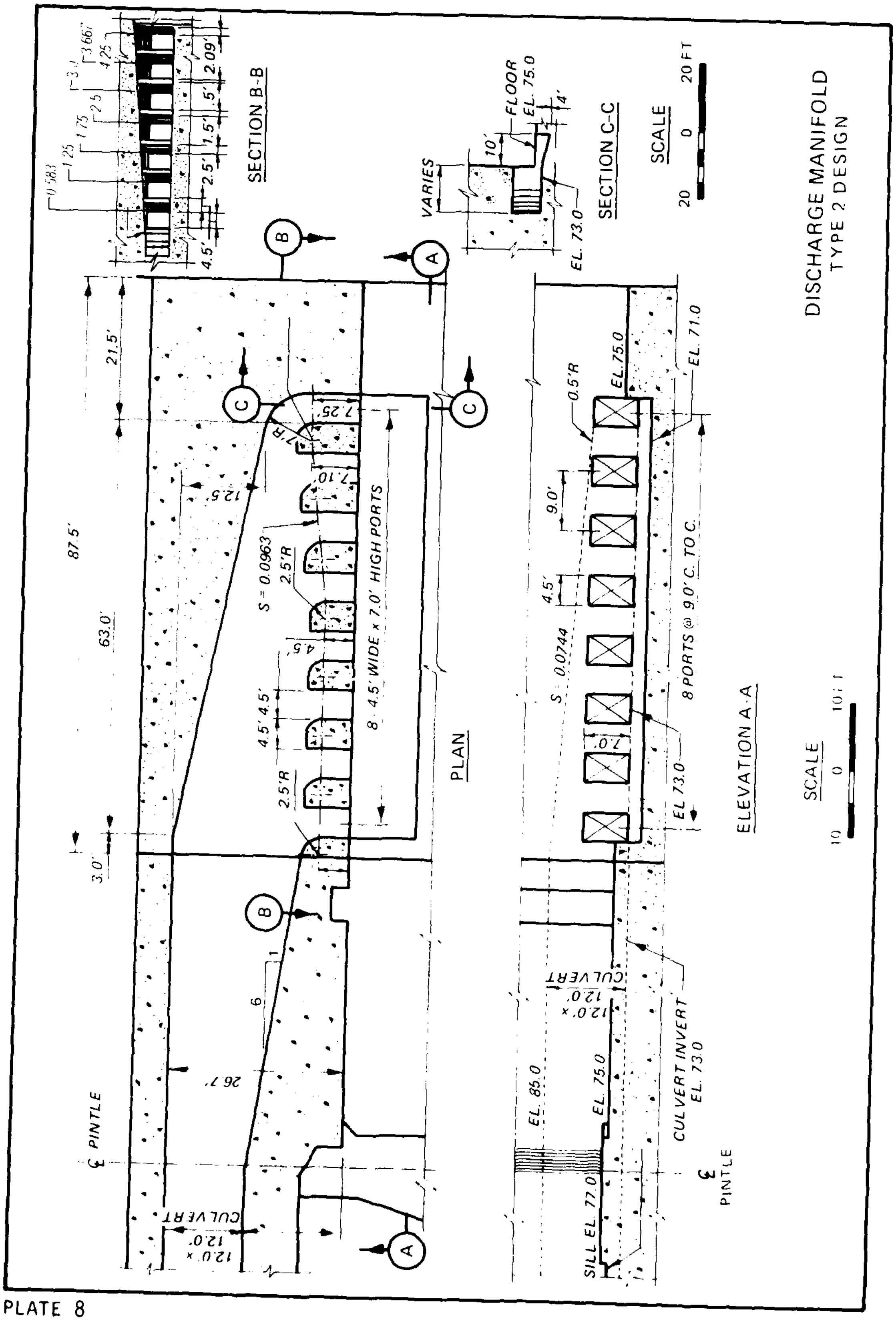
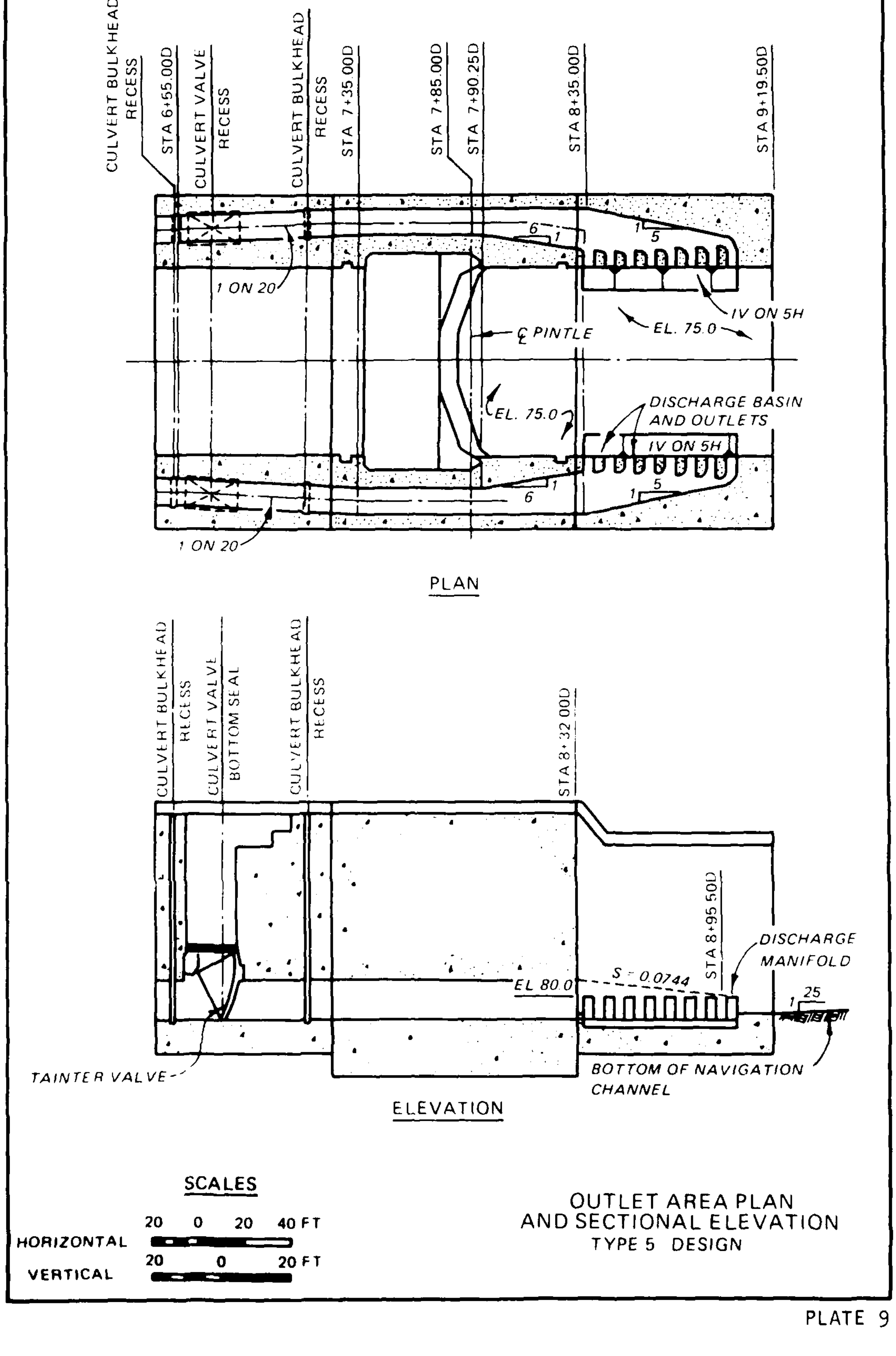
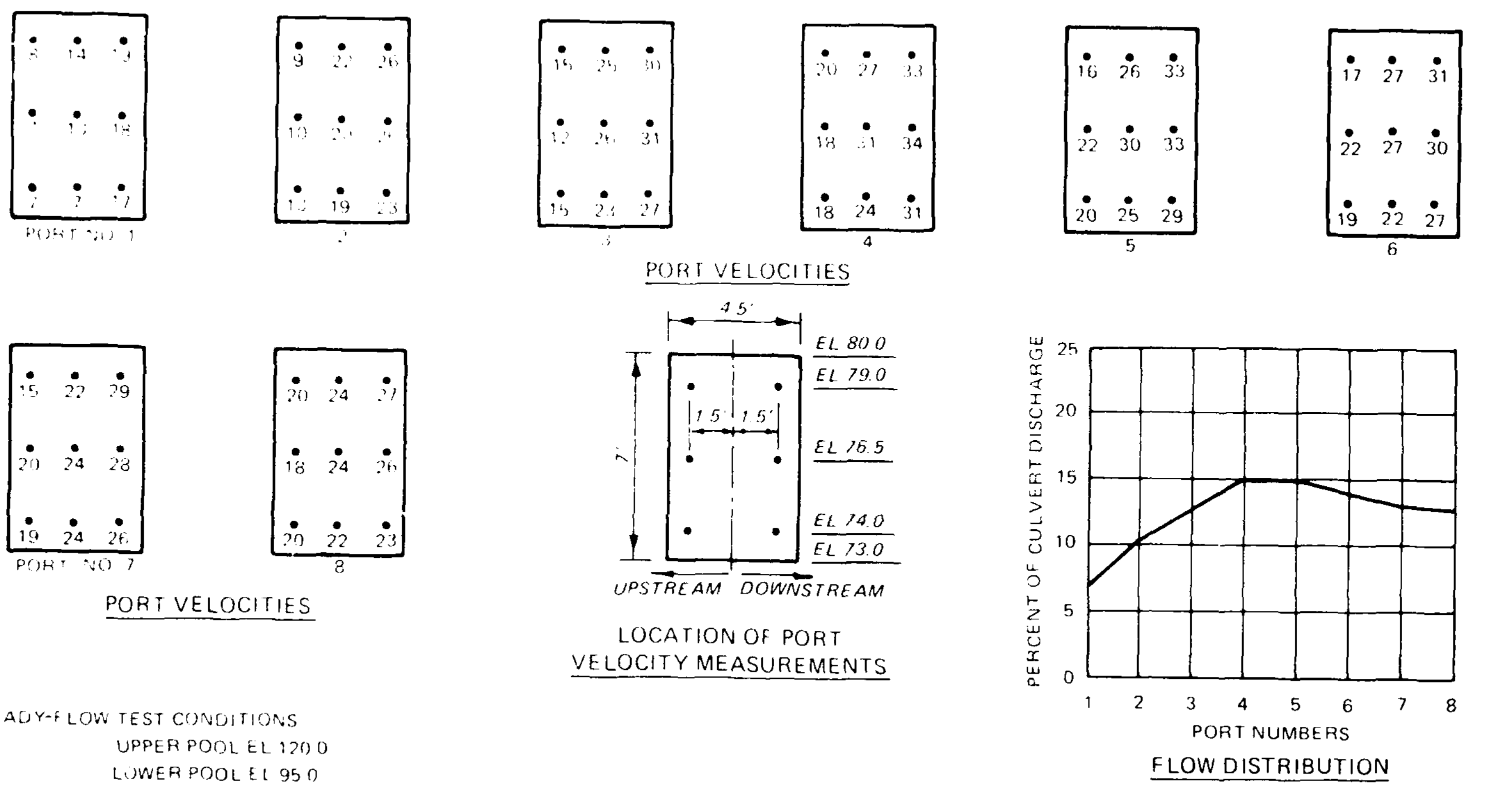

DISCHARGE MANIFOLD
TYPE 2 DESIGN
SECTION B-B
SECTION C-C
PLAN
ELEVATION A-A
SCALE
8 - 4.5' WIDE x 7.0' HIGH PORTS
8 PORTS @ 9.0' C. TO C.
S = 0.0963
S = 0.0744
12.0' x 12.0' CULVERT
CULVERT INVERT EL. 73.0
SILL EL. 77.0
EL. 85.0
EL. 75.0
EL. 73.0
EL. 71.0
FLOOR EL. 75.0
VARIES
℄ PINTLE
87.5'
63.0'
21.5'
3.0'
26.7'
12.5'

PLATE 8



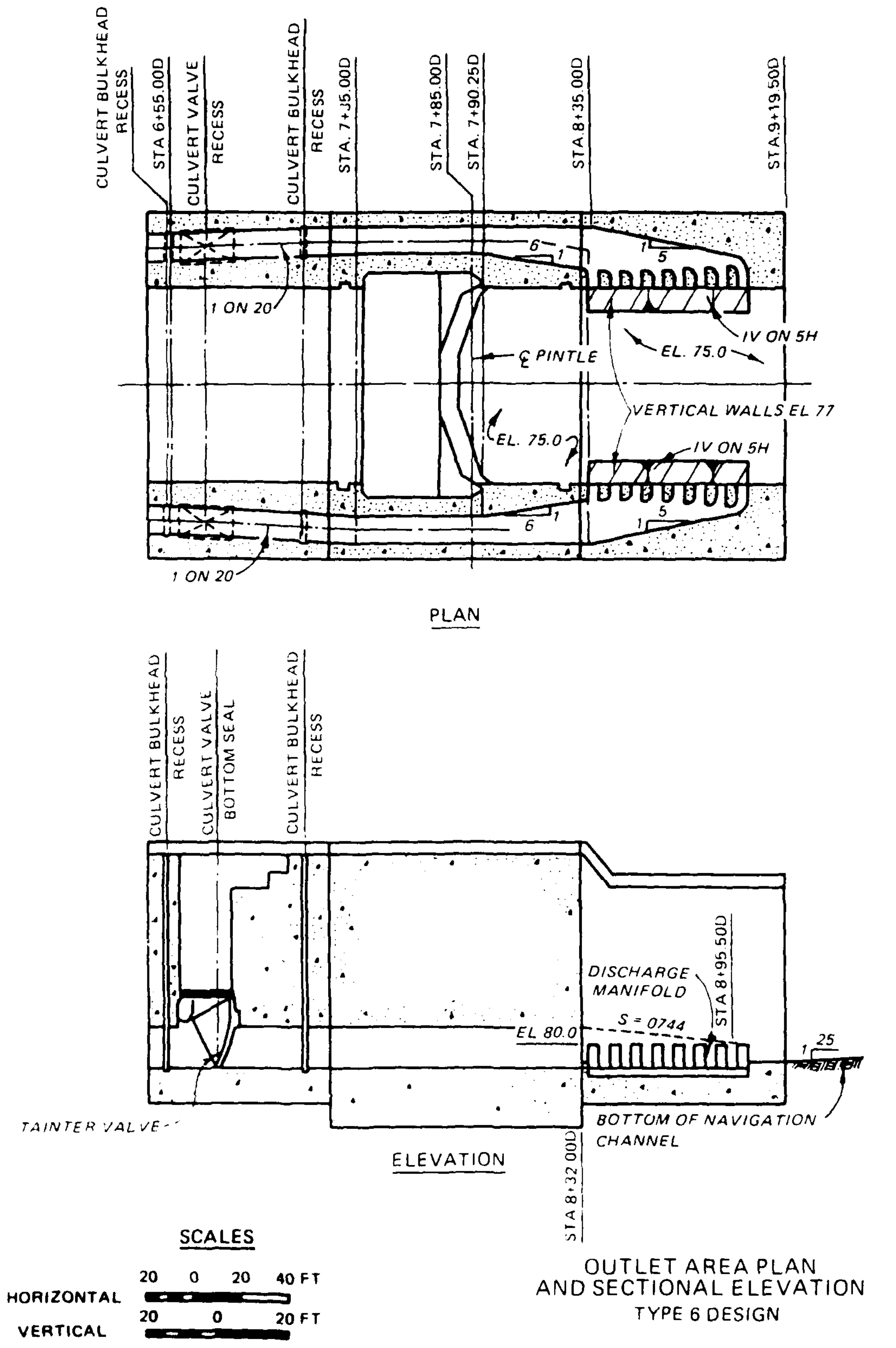

OUTLET AREA PLAN AND SECTIONAL ELEVATION
TYPE 5 DESIGN



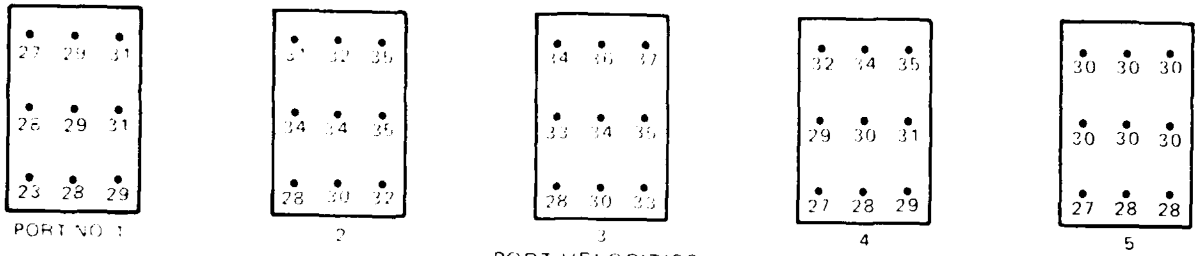

STEADY-FLOW TEST CONDITIONS
UPPER POOL EL 120.0
LOWER POOL EL 95.0
EMPTY VALVES FULL OPEN

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND

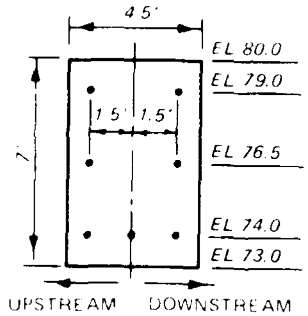
VELOCITIES AT DISCHARGE MANIFOLD PORTS
TYPE 2 DESIGN DISCHARGE MANIFOLD



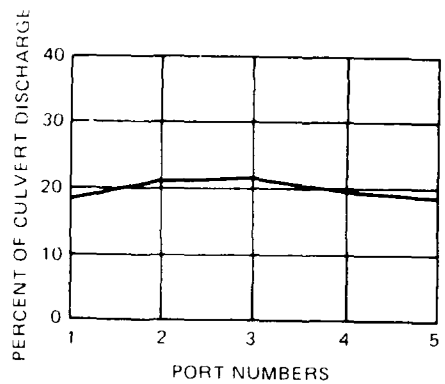

OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 6 DESIGN




PORT VELOCITIES




LOCATION OF PORT VELOCITY MEASUREMENTS

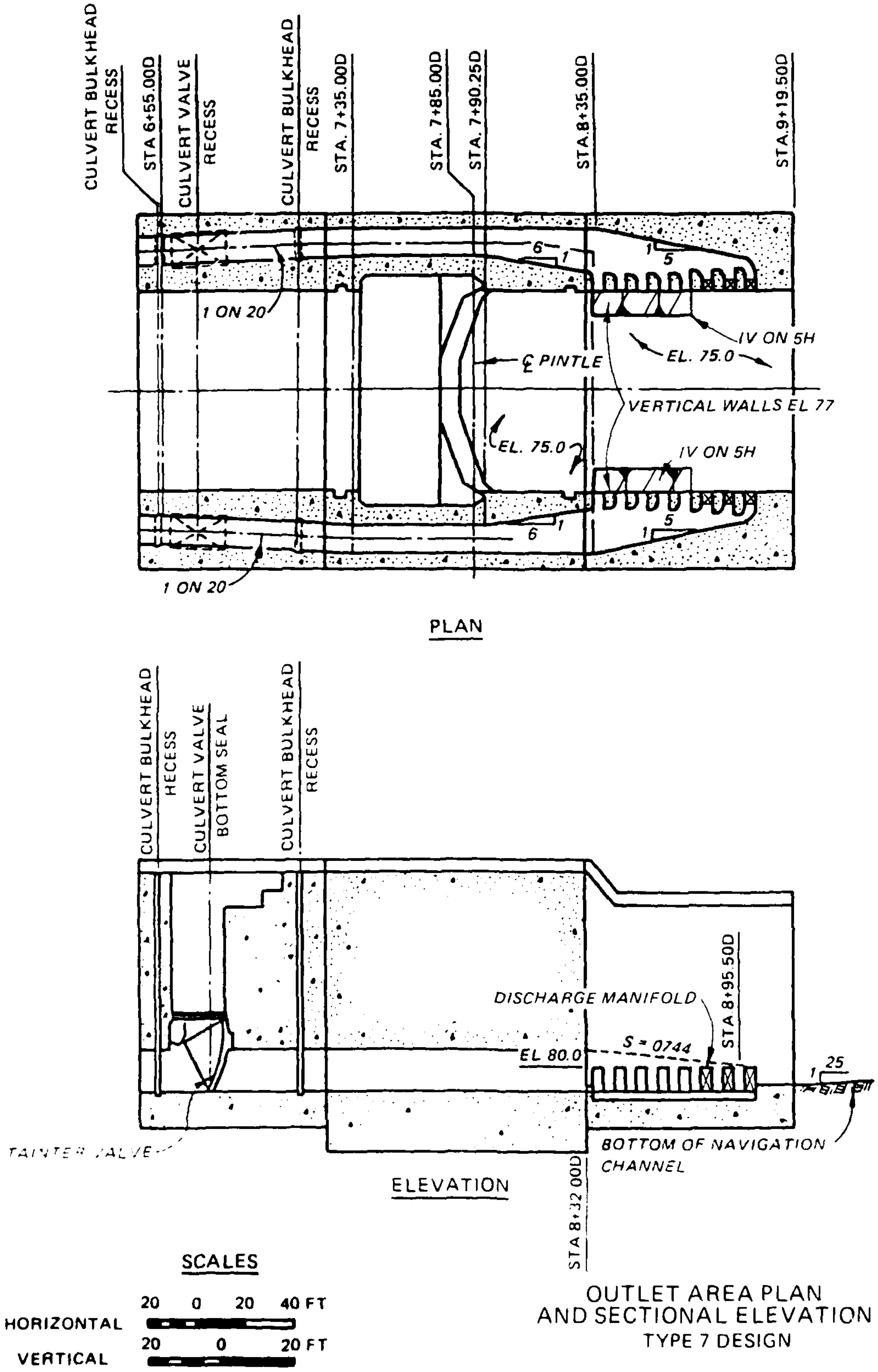



FLOW DISTRIBUTION

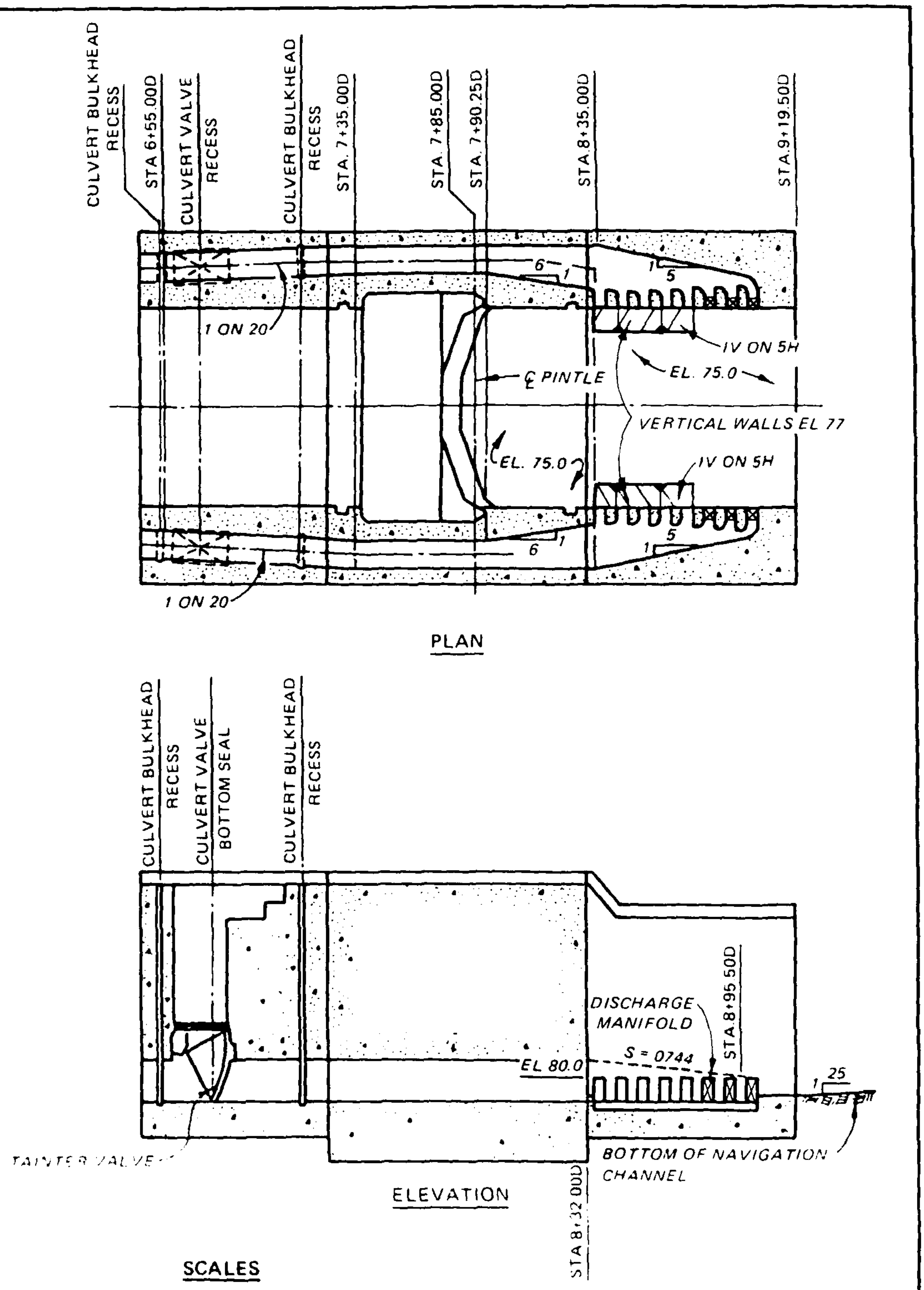
STEADY-FLOW TEST CONDITIONS
UPPER POOL EL 120.0
LOWER POOL EL 95.0
EMPTY VALVES FULL OPEN

NOTE  VELOCITIES ARE IN PROTOTYPE FEET PER SECOND

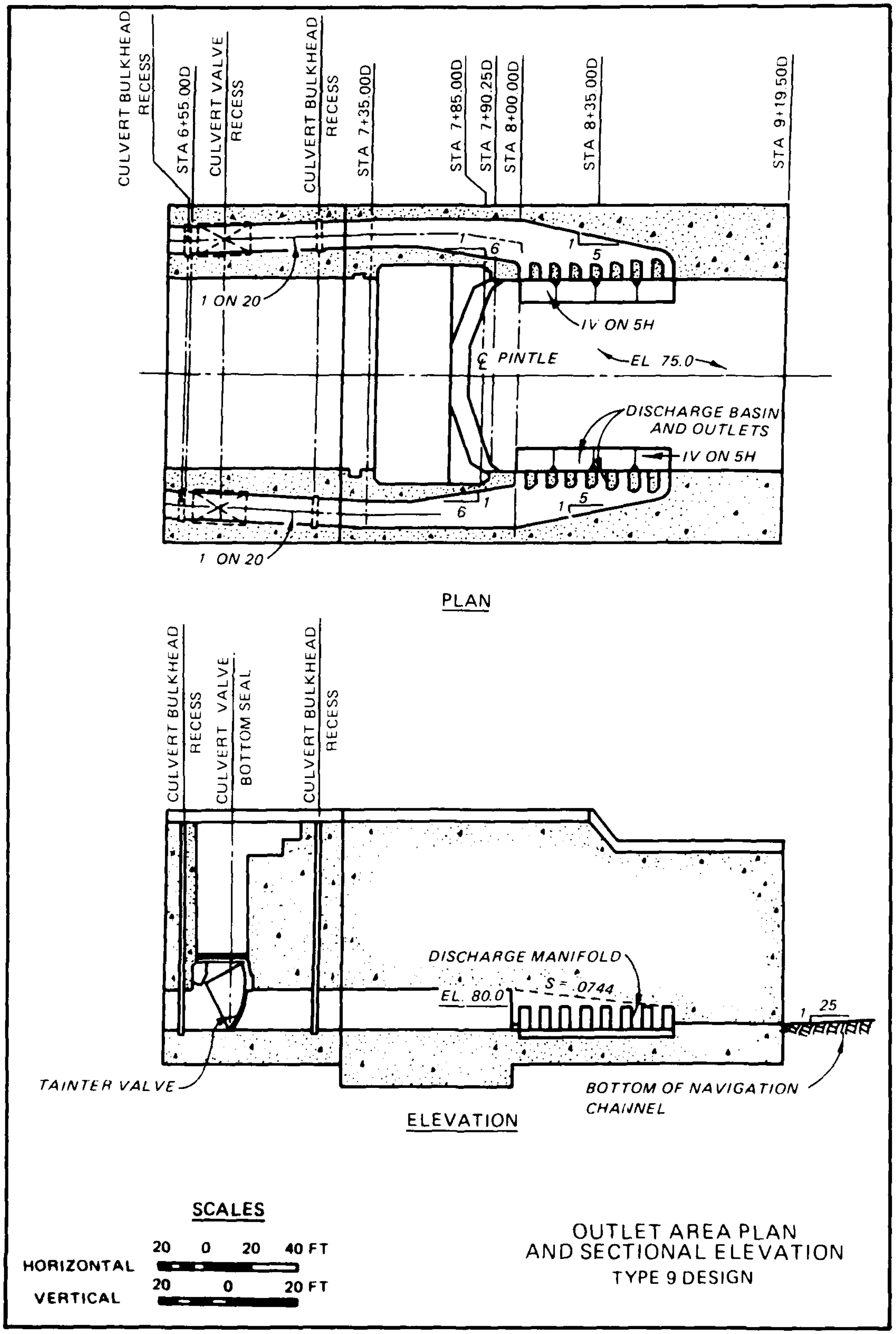
VELOCITY AT DISCHARGE MANIFOLD PORTS
TYPE 3 DESIGN DISCHARGE MANIFOLD



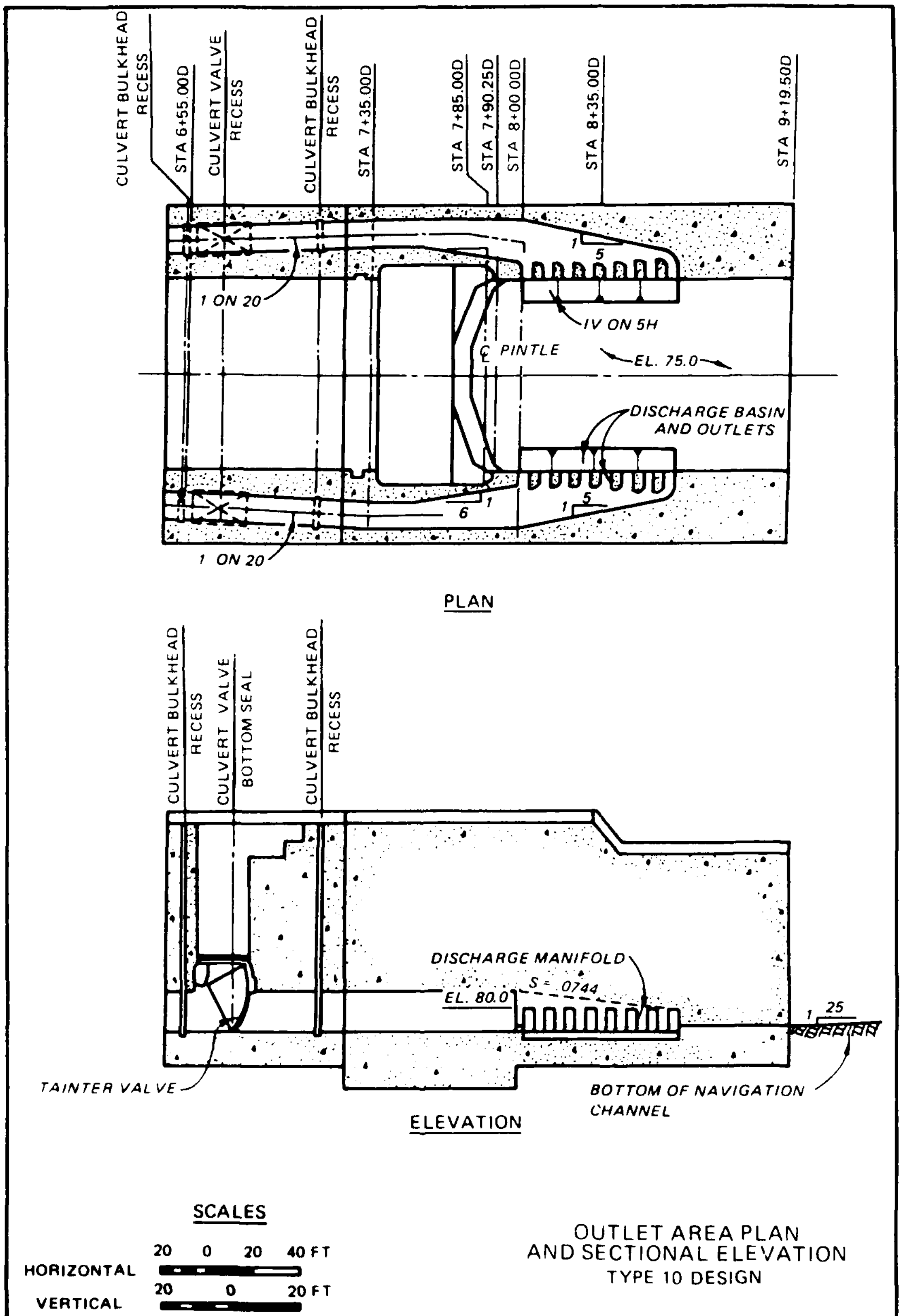

OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 7 DESIGN



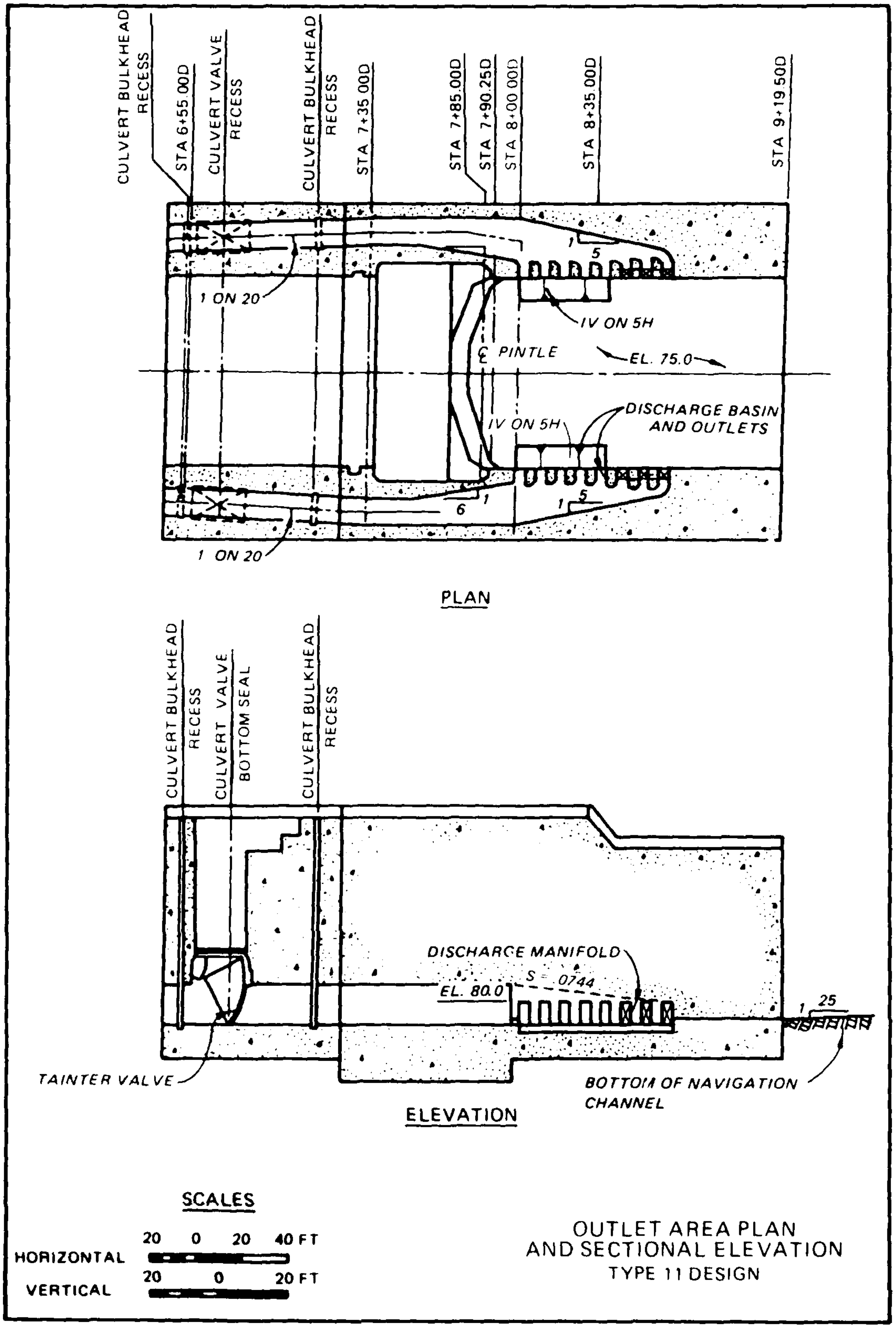

OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 8 DESIGN



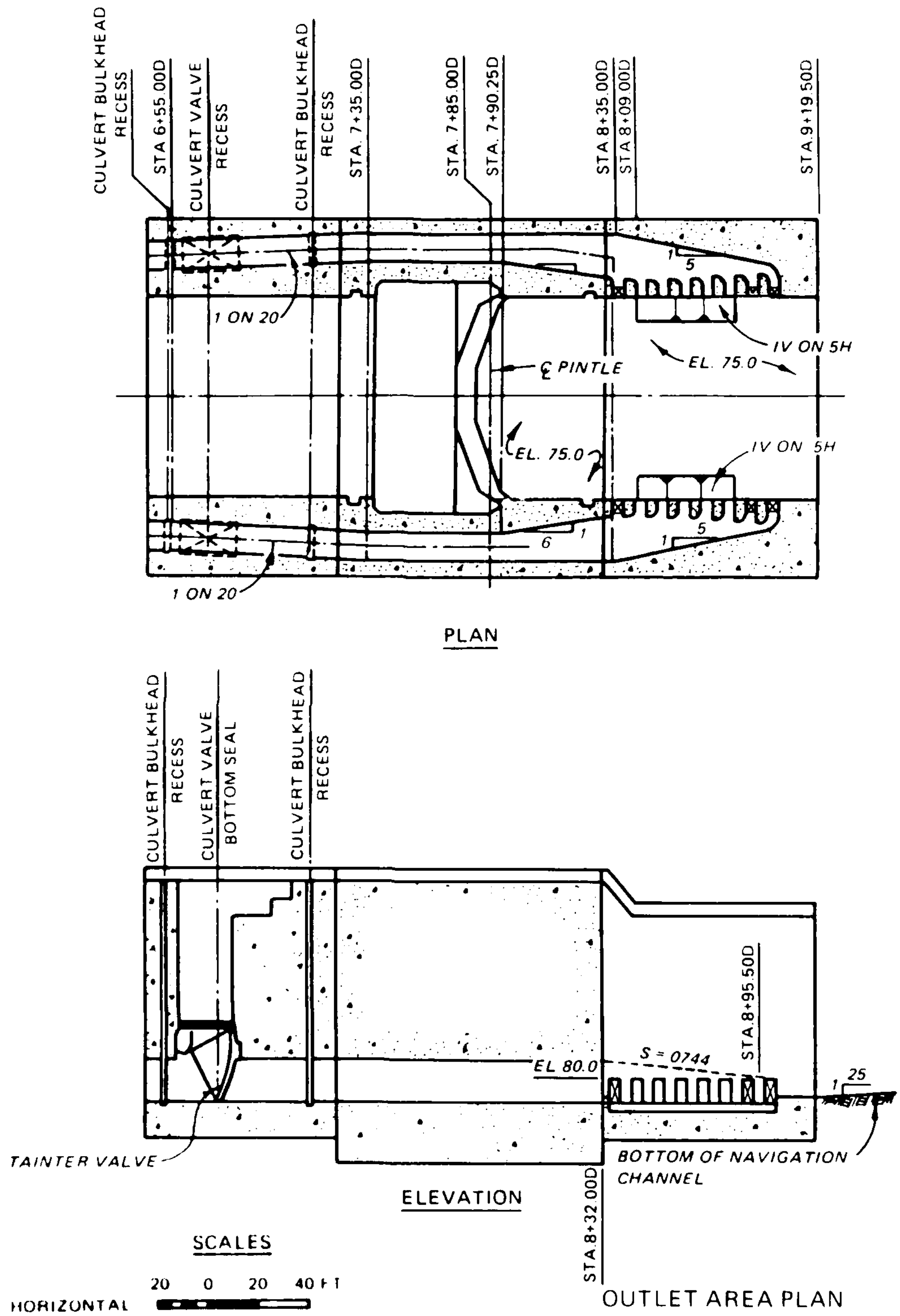

OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 9 DESIGN



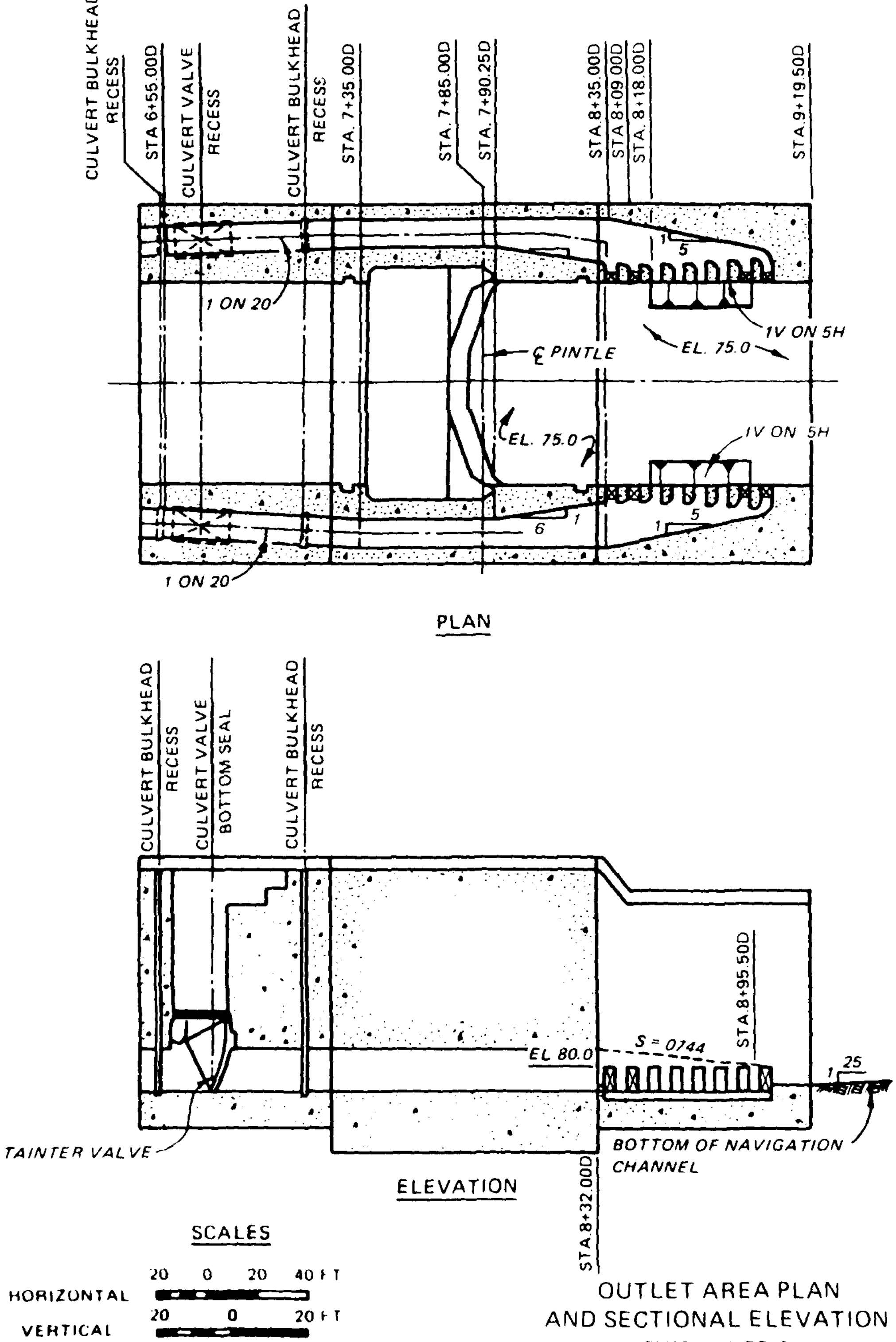

OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 10 DESIGN




OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 11 DESIGN




OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 12 DESIGN




OUTLET AREA PLAN
AND SECTIONAL ELEVATION
TYPE 13 DESIGN